In-Training Examination
for Radiation Oncology Residents

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1. A 66-year old female with pT1 pN0(sn) grade 2 ER + breast cancer is treated with breast conserving surgery with negative margins and intends to take endocrine therapy. What is the risk of ipsilateral breast tumor recurrence at 5 years without RT?

A. 1%
B. 4%
C. 9%
D. 15%

Key: B

Rationale:
On the PRIME II study of breast conserving surgery with or without radiation in women =65 yrs of age with early low risk breast cancer and receiving endocrine therapy, rates of ipsilateral breast tumor recurrence at 5 yrs were 1.3% with whole breast radiation vs 4.1% without radiation (p=0.0002). These rates were 1.8% vs. 5.6%, respectively if axillary recurrences were included.

Reference:

2. What is the MOST appropriate study to assess baseline swallowing function in a person with newly diagnosed larynx cancer who coughs after drinking or eating?

A. Chest X-ray
B. Esophagram
C. Pulmonary function test
D. Modified barium swallow study

Key: D

Rationale:
Aspiration is frequently reported in clinical studies using the modified barium swallow study (MBS). Coughing is often a sign of aspiration, which is common amongst larynx cancer patients. Due to impaired sensory awareness, many patients under-report aspiration which can be detected on MBS.

Reference:
3. What was the total preoperative RT dose for initially unresectable vulvar cancer in the GOG 205 study when given along with weekly cisplatin chemotherapy?

A. 45 Gy
B. 50.4 Gy
C. 57.6 Gy
D. 63 Gy

Key: C

Rationale:
The total dose was 57.6 Gy in 32 fractions to gross disease, given along with weekly cisplatin chemotherapy. At 45 Gy, radiation fields were reduced in size. The complete clinical response rate was 64%. An optimal preoperative or definitive dose schedule for vulvar cancer remains not well defined.

Reference:

4. What is an advantage of a cross-over study?

A. carry-over effect
B. increased drop-out
C. efficiency increase
D. slow recruitment

Key: C

Rationale:
The carry-over effect, increased drop-out, increase efficiency, and fast recruitment are characteristics in a cross-over study. Efficiency increase is an advantage.

Reference:
5. Which of the following respiratory motion management techniques for liver SBRT would result in the LARGEST PTV for the same tumor?

   A. ITV generated with 4D CT
   B. Respiratory gating
   C. Abdominal compression
   D. Deep inspiration breath hold

**Key:** A

**Rationale:**
A generates an ITV spanning the entire range of motion of the tumor creating the largest treatment volume. Respiratory gating only radiates when the tumor (or reference point) is within a defined treatment window. Abdominal compression reduces the range of motion by measure of physically compressing the abdomen. Active breath hold techniques have the patient hold their breath in a specific position, effectively fixing the tumor in space, and reducing the range of motion.

**Reference:**
The Management of Respiratory Motion in Radiation Oncology Report of AAPM Task Group 76.

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6. What is the appropriate surveillance plan for a patient with stage I seminoma undergoing observation after an orchiectomy?

   A. Abdominal and Pelvic CT at 6 and 12 months
   B. Chest, Abdominal and Pelvic CT at 6 and 12 months
   C. Abdominal and Pelvic CT at 3, 6 and 12 months
   D. Chest, Abdominal and Pelvic CT at 3, 6 and 12 months

**Key:** C

**Rationale:**
The NCCN recommends an abdominal and pelvic CT at 3, 6, and 12 months in the first year following orchiectomy.

**Reference:**
7. According to the RTOG breast cancer contouring atlas, what is included in the chest wall CTV for a patient receiving PMRT?

A. Mastectomy scar and chest wall excluding pectoralis muscles and ribs  
B. Mastectomy scar and chest wall including pectoralis muscles and excluding ribs  
C. Mastectomy scar and chest wall including pectoralis muscles and ribs, excluding latissimus dorsi muscle  
D. Mastectomy scar and chest wall including pectoralis muscles, ribs, and latissimus dorsi muscle  

**Key:** C  

**Rationale:**  
According to the RTOG breast contouring atlas, the chest wall CTV includes the mastectomy scan and incorporates the clinical chest wall and includes the skin, pectoralis muscles, chest wall muscles and ribs and typically excludes the latissimus dorsi muscle.

**Reference:**  

8. A female with a cT3N1M0 ER/PR- Her2 + breast cancer receives neoadjuvant TCHP followed by a mastectomy with sentinel lymph node biopsy and achieves a pCR. What adjuvant therapy is recommended?

A. Continue a full year of trastuzumab +/- pertuzumab with no RT  
B. RT to the chest wall and regional lymph nodes with concurrent trastuzumab +/- pertuzumab  
C. RT to the chest wall and regional lymph nodes with concurrent TDM-1  
D. RT to the chest wall only with concurrent TDM-1  

**Key:** B  

**Rationale:**  
This patient has a clinical stage III breast cancer and data from M.D. Anderson suggests high local recurrence risk in the setting of a pCR for stage III breast cancer not treated with radiation. In the KATHERINE trial, TDM-1 was reserved for patients with residual disease after neoadjuvant chemotherapy with trastuzumab.

**Reference:**  
9. At what minimum depth of invasion should lymph node dissection be considered for oral tongue squamous cell carcinoma?

   A. 1.5 mm  
   B. 3 mm  
   C. 4.5 mm  
   D. 6 mm

**Key:** B

**Rationale:**
Lymphatic channels occur in the oral tongue at a depth of 3 mm or greater, and tumors exhibiting this depth of invasion should undergo evaluation for lymph node involvement (by imaging and/or elective dissection). Depth of invasion, with a cutoff of 3 mm, was predictive of regional nodal recurrence in multiple studies.

**Reference:**

10. Number needed to treat (NNT) is calculated as the reciprocal of the:

   A. relative risk (RR) for an adverse outcome between control and treatment groups.  
   B. odds ratio (OR) for an adverse outcome between control and treatment groups.  
   C. relative risk reduction (RRR) for an adverse outcome between control and treatment groups.  
   D. absolute risk reduction (ARR) for an adverse outcome between control and treatment groups.

**Key:** D

**Rationale:**
By definition, NNT is the reciprocal of the absolute risk reduction.

**Reference:**
Schechtman, E. (2002). Odds ratio, relative risk, absolute risk reduction, and the number needed to treat—which of these should we use? Value in Health, 432.
11. In the ASCENDE-RT randomized trial of intermediate and high-risk prostate cancer testing the role of brachytherapy boost to ADT+ EBRT, what was observed in the cohort that received brachytherapy?

A. Decreased toxicity, improved OS
B. Increased toxicity, improved OS
C. Increased toxicity, improved freedom from biochemical failure
D. Increased toxicity, decreased freedom from biochemical failure

Key: C

Rationale:
Compared with 78 Gy external beam radiation, men randomized to the brachytherapy boost were twice as likely to be free of biochemical failure at a median follow-up of 6.5 years. The incidence of acute and late GU morbidity was higher after brachytherapy boost, and there was a nonsignificant trend for worse GI morbidity.

Reference:

12. On the CARTS study for cT1-T3N0 rectal cancer treated with chemoradiation followed by transanal endoscopic microsurgery, what was the local recurrence rate at 5 years?

A. 2%
B. 8%
C. 14%
D. 20%

Key: B

Rationale:
Following ChemoRT, 47 patients (85%) underwent TEM, of whom 35 (74%) were successfully treated with local excision alone. Total mesorectal excision was performed in 16 patients (4 with inadequate responses, 8 with completion after TEM, and 4 with salvage for local recurrence). The actuarial 5-year local recurrence rate was 7.7%, with 5-year disease-free and overall survival rates of 81.6% and 82.8%, respectively.

Reference:
13. What is the estimated rate of radionecrosis in modern studies following intracranial radiosurgery alone?

A. 1%
B. 5%
C. 9%
D. 13%

**Key:** B

**Rationale:**
A randomized study comparing SRS vs. SRS + WBRT by Brown and colleagues reported a 4.5% rate of radionecrosis in patients receiving SRS alone (compared to 2.9% in patients receiving SRS + WBRT).

**Reference:**
PD Brown, et al. (2016). Effect of Radiosurgery Alone vs Radiosurgery With Whole Brain Radiation Therapy on Cognitive Function in Patients With 1 to 3 Brain Metastases: A Randomized Clinical Trial. JAMA.

14. Based on the Milan criteria, which of the following would be a CONTRAINDICATION for a liver transplant?

A. A single tumor measuring 4.5 cm
B. Tumor involving the caudate lobe and portal vein
C. Two tumors, one measuring 2.5 cm and one measuring 1.0 cm
D. Three tumors, one measuring 2.5 cm, one 2.0 cm, and one 1.0 cm

**Key:** B

**Rationale:**
Milan criteria is the accepted standard for undergoing liver transplantation. To meet Milan criteria, patients must have either a single tumor ≤ 5 cm in size or ≤ 3 tumors each ≤ 3 cm in size, and no macrovascular invasion. All options are within Milan criteria, except for B, which has vascular involvement.

**Reference:**
15. What is the MOST commonly prescribed dose for ocular melanoma eye plaques at 5 mm depth or at tumor apex?

A. 55 Gy  
B. 70 Gy  
C. 85 Gy  
D. 100 Gy

Key: C

Rationale:
The American Association of Physicists in Medicine (AAPM) and American Brachytherapy Society (ABS) review indicates the most commonly used prescription dose for ocular melanoma eye plaques is 85 Gy at 5 mm depth when using (125)I and (103)Pd sources.

Reference:

16. In the CRITICS trial, which randomized patients to receive chemotherapy (CT) or chemoradiotherapy (CRT) after preoperative chemotherapy and surgery for gastric cancer, what was seen with postoperative CRT versus CT?

A. Improved OS  
B. Increased rates of febrile neutropenia  
C. Decreased treatment compliance  
D. No significant difference in OS

Key: D

Rationale:
The CRITICS trial (Cats A, Lancet Oncol 2018) yielded median survival of 43 months in the chemotherapy group and 37 months in the chemoradiotherapy group (p=0.90), therefore there was no indication that postoperative CRT improved survival compared to CT in this study.
17. The recently presented RADICALS-RT trial showed which of the following with the use of adjuvant RT when compared to early salvage RT after prostatectomy?

A. Increased GI toxicity, improved biochemical control  
B. No difference in GU toxicity, improved biochemical control  
C. Improved metastasis free survival, improved biochemical control  
D. Increased GI toxicity, no difference in biochemical control  

**Key:** D  

**Rationale:**  
The RADICALS trial was a randomized trial in 1396 men with intermediate to high risk prostate cancer who had undergone radical prostatectomy and had a post-operative PSA < 0.2 ng/ml and one or more of the follows: pT3/4 disease, Gleason 7-10 disease, preoperative PSA ≥ 10 ng/ml, and positive surgical margins. Patients were randomized to either adjuvant radiation therapy or early salvage radiation therapy which was administered with 2 consecutive PSA rises and PSA > 0.1 ng/ml or 3 consecutive rises regardless of the PSA. The results showed no difference in biochemical control, and worse toxicity in the adjuvant radiation therapy arm.  

**Reference:**  

18. What was the difference in 3-year OS between HPV+ and HPV- oropharyngeal cancer patients in the RTOG 0129 trial?

A. 5%  
B. 25%  
C. 45%  
D. 65%  

**Key:** B  

**Rationale:**  
The 3-year rates of overall survival were 82.4% (95% CI, 77.2 to 87.6) in the HPV + subgroup and 57.1% (95% CI, 48.1 to 66.1) in the HPV – subgroup. The significantly lower tumor related mortality rate for HPV+ tumors in this trial served as the basis for subsequent and ongoing trials testing treatment de-escalation approaches in HPV+ disease.  

**Reference:**  
19. Which of the following soft tissue sarcoma histologic subtypes is associated with higher probability of volumetric change during pre-operative RT?

A. Leiomyosarcoma  
B. Myxofibrosarcoma  
C. Myxoid liposarcoma  
D. Undifferentiated pleomorphic sarcoma

**Key:** C

**Rationale:**
In a retrospective review of 99 patients with extremity soft tissue sarcoma (ESTS) treated with radiation and CTV to PTV margin of 1 cm, an extremity contour change of >1 cm and/or tumor size change >0.5 cm required a physician’s action before the next fraction. A total of 982 cone beam computed tomography logfiles were studied. ESTS volumes were found to change substantially during RT in 59% of all patients, leading to plan adaptations resulting from increased volumes in 8%. Initial sarcoma size larger than the median of 10 cm (n=45, P=.02) and myxoid liposarcoma pathology (n=14, P=.03) were statistically significantly correlated with a higher probability of contour changes on treatment.

**Reference:**

20. For primary liver tumors, what is the most appropriate dose constraint for mean liver dose in partial liver irradiation in daily doses of 2 Gy?

A. 28 Gy  
B. 32 Gy  
C. 36 Gy  
D. 40 Gy

**Key:** A

**Rationale:**
For therapeutic partial liver RT (standard fractionation), recommended Mean normal liver dose (liver minus gross tumor volume): < 28 Gy in 2-Gy fractions for primary liver cancer; < 32 Gy in 2-Gy fractions for liver metastases.

**Reference:**
21. What is the sensitivity of a diagnostic test to identify disease?

A. True positives/ (True positives + False positives)
B. True positives/ (True positives + False negatives)
C. True negatives/ (True negatives + False negatives)
D. True negatives/ (True negatives + False positives)

**Key:** B

**Rationale:**
Using a standard 2 x 2 model to describe population and testing the definition of Sensitivity is True positives/true positives + false negatives, hence choice (B) is correct.

Choice (A) is the correct definition for positive predictive value
Choice (C) is the correct definition for negative predictive value
Choice (D) is the correct definition for positive predictive value

**Reference:**
“The Evidence-based Medicine Paradigm: Where are We 20 Years Later? Part 1”. Seshia SS, Young GB; Can J Neurol Sci. 2014; 41(1); 129.

22. Which is a tumor characteristic associated with BRCA 1+ breast cancer?

A. Lobular histology
B. Triple negative receptor staining (ER-, PR-, HER-2/Neu-)
C. Tubular component
D. HER-2/Neu amplification

**Key:** B

**Rationale:**
BRCA 1 associated breast cancers are typically triple negative whereas BRCA 2 associated breast cancers are more often hormone receptor positive.

**Reference:**
23. Which of these breast cancer histologies is MOST favorable?

A. Apocrine  
B. Pleomorphic lobular  
C. Medullary  
D. Metaplastic  

Key: C  

Rationale:  
Medullary carcinomas are typically hormone receptor positive, are rarely associated with nodal positivity, and have high rates of local control. Apocrine carcinomas are typically hormone receptor negative are of intermediate prognosis. Pleomorphic lobular carcinomas and metaplastic carcinomas are typically high grade and associated with poor prognosis.  

Reference:  

24. What were the inclusion criteria for the ACOSOG Z6041 study evaluating neoadjuvant chemoradiation and local excision for rectal cancer?

A. cT1N1 with < 30% of the circumference of the rectum  
B. cT2N0 with < 40% of the circumference of the rectum  
C. cT2N1 with < 30% of the circumference of the rectum  
D. cT3N0 with < 40% of the circumference of the rectum  

Key: B  

Rationale:  
The ACOSOG Z6041 included clinically staged T2N0 distal rectal cancer treated with neoadjuvant chemoradiotherapy. Patients with clinical T2N0 rectal adenocarcinoma staged by endorectal ultrasound or endorectal coil MRI, measuring less than 4 cm in greatest diameter, involving less than 40% of the circumference of the rectum, located within 8 cm of the anal verge, and with an Eastern Cooperative Oncology Group performance status of at least 2 were included in the study were studied.  

Reference:  
25. What type of trial is used to determine maximum tolerated dose (MTD)?

A. Phase I
B. Phase II
C. Phase III
D. Phase IV

**Key:** A

**Rationale:**
Phase III trials are large trials involving hundreds to thousands of patients, in which further corroboration of early success (Phase II) with a particular drug or intervention is being confirmed. Phase IV provide additional efficacy or safety data after the new intervention has been approved by regulatory agencies.

**Reference:**
“Clinical Trial Design and Methodology” ASCO online
https://www.asco.org/research-progress/clinical-trials/clinical-trial-resources/clinical-trial-design-and-methodology

26. What is the median?

A. The arithmetic average
B. The most frequent value
C. The value that divides a group of numbers in half
D. The minimum of a group of ranked numbers

**Key:** C

**Rationale:**
Median is the middle number that divides the group into halves.

**Reference:**
27. Which solid tumor histology has the HIGHEST rate of leptomeningeal spread?

A. Renal cell carcinoma  
B. Non-small cell lung cancer  
C. Ovarian cancer  
D. Melanoma

Key:  D  

Rationale:  
Melanoma has the highest rate of leptomeningeal spread, while other common cancers include breast and lung.

Reference:  
28. A 72-year-old woman with history of squamous cell carcinoma of the left nasal bridge treated with excision now presents with pain and numbness involving the left cheek, medial nose, and jaw, and develops ipsilateral facial paralysis. On review of the MRI, involvement of which nerve is the MOST likely explanation for the paralysis?

A. Distal maxillary nerve (V2)
B. Proximal maxillary nerve (V2)
C. Facial nerve (VII) through the corda tympani
D. Facial nerve (VII) through the pterygopalatine ganglion

Key:
This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores)

Rationale:
This anatomy question relates to perineural spread of disease, an important consideration when treating advanced skin cancers. There are several communications between the facial and trigeminal nerve systems. The MRI in this case shows clear enhancement along the entire trunk of the maxillary nerve, with likely further spread through the pterygopalatine ganglion and along the vidian nerve to the facial nerve responsible for the facial paralysis.

Reference:
29. What is the AJCC stage group for a 1.7 cm squamous cell carcinoma of the vulva, metastatic to 2 bilateral inguinal lymph nodes, with each metastatic focus measuring < 5 mm in size?

A. II  
B. IIIA  
C. IIIB  
D. IIIC

**Key:** B

**Rationale:**
In the most current AJCC vulvar cancer staging rules, laterality of nodal metastases does not affect the nodal stage, but the size and the number of involved lymph nodes do.

**Reference:**

30. Per RTOG 1112, which is an appropriate dose constraint for liver SBRT (delivered in 5 fx)?

A. Mean liver-GTV dose 21 Gy  
B. Max point dose for small bowel (0.05cc) 38 Gy  
C. Max point dose for gallbladder (0.05cc) 38 Gy  
D. Max spinal cord dose 45 Gy

**Key:** C

**Rationale:**
Per RTOG1112, the maximum mean liver dose should be 17 Gy. The maximum point dose for small bowel in 5 fractions is 32 Gy and the max dose for large bowel (colon) is 38 Gy, making the constraint for large bowel within tolerance. The spinal cord tolerance in 5 fractions is 30 Gy (for conventionally fractionated radiation 45 Gy is within tolerance).

**Reference:**
31. Which condition is associated with clear cell renal cell carcinoma?

A. Lynch Syndrome  
B. Gorlin Syndrome  
C. Von Hippel-Lindau Disease  
D. Ataxia-Telangiectasia

**Key:** C

**Rationale:**
Von Hippel-Lindau disease is an autosomal dominant syndrome that gives predisposes individuals to the development of highly vascularized tumors. The main manifestations include clear-cell renal cell carcinomas, central nervous system and retinal haemangioblastomas, endolymphatic sac tumors, phaeochromocytomas and pancreatic neuroendocrine tumors. Von Hippel-Lindau disease is caused by mutations in the VHL tumor-suppressor gene.

32. Patients with which known pathogenic mutation are at increased risk of breast and ovarian cancer and should be counseled on risk-reducing mastectomy and salpingo-oopherectomy?

A. ATM  
B. BRCA2  
C. PTEN  
D. TP53

**Key:** B

**Rationale:**
Pathogenic mutations in BRCA1 and BRCA2 confer significant increase risk for breast and ovarian cancer and the NCCN guidelines recommend that option for risk-reducing mastectomy (RRM) be discussed and recommend risk-reducing salpingo-oopherectomy (RRSO). For ATM mutations: increased risk of breast cancer but evidence for RRM insufficient, manage based on family history, and potential increase in ovarian cancer but insufficient evidence to recommend RRSO. For PTEN and TP53 mutations: increased risk for breast cancer and no increased risk for ovarian cancer. The NCCN guidelines recommend discussion of RRM for deleterious TP53 or PTEN mutations.

**Reference:**
33. What imaging feature is characteristic of a low grade oligodendroglioma?

A. Hemorrhage
B. Calcifications
C. Occipital lobe location
D. Ring-enhancement

**Key:** B

**Rationale:**
Low grade oligodendrogliomas are typically non-enhancing, sometimes with calcifications, and located in cortical-subcortical locations in the frontal or temporal lobes. They also typically have heterogenous signal intensity of T2 weighted MRI scans and indistinct borders. Higher-grade gliomas including glioblastomas are typically ring-enhancing with hemorrhage and necrosis on imaging.

34. What is hybrid brachytherapy in cervical cancer?

A. Interdigitated EBRT and brachytherapy
B. Combination of intracavitary and interstitial source placement
C. Delivery of brachytherapy after EBRT
D. Addition of weekly chemotherapy

**Key:** B

**Rationale:**
Hybrid brachytherapy is useful in cervical cancer with unfavorable disease geometry after EBRT (e.g. residual parametrial tumor extension). In hybrid implants, the placement of a standard tandem + ring or tandem + ovoids devices is combined with the insertion of a limited number of parametrial needles. Needles are usually placed through vaginal fornices and the procedure is facilitated by commercially available applicators. The schedule of hybrid brachytherapy does not differ from pure intracavitary procedures.

**Reference:**
35. For locoregionally advanced NPC, which induction chemotherapy regimen given prior to concurrent chemoRT improved OS compared to standard in a randomized controlled Phase III trial?

A. Cetuximab  
B. Carboplatin and paclitaxel  
C. Gemcitabine and cisplatin  
D. Carboplatin and 5-fluorouracil  

**Key:** C  

**Rationale:**  
A Phase III randomized controlled trial compared gemcitabine and cisplatin as induction chemotherapy plus concurrent chemoradiotherapy with concurrent chemoradiotherapy alone. At a median follow-up of 42.7 months, the primary endpoint of 3-year recurrence-free survival was improved in the induction arm compared to the standard-therapy arm (HR 0.51; 95% confidence interval [CI], 0.34-0.77; P=0.001). The 3-year overall survival was significantly better in the induction arm (HR 0.43; 95% CI, 0.24 to 0.77).  

**Reference:**  

36. What was the maximum grade toxicity on the phase II SABR-COMET trial that showed use of SABR was associated with improved OS vs standard palliative treatment in patients with oligometastatic cancer?

A. Grade 2  
B. Grade 3  
C. Grade 4  
D. Grade 5  

**Key:** D  

**Rationale:**  
The SABR-COMET trial enrolled 99 patients with oligometastatic cancer (controlled primary tumor and 1 to 5 metastatic lesions, most had 1-3 mets). Primary tumors included breast, colorectal, lung, prostate, and others. Patients were randomized 2:1 to standard of care plus SABR to all mets (n = 66) or to standard of care palliative treatment, including RT (n = 33). SABR was associated with an improvement in OS (41 vs 28 mos), meeting the primary endpoint of this trial, but 3 (4.5%) of 66 patients in the SABR group had treatment-related death (due to radiation pneumonitis, pulmonary abscess, and subdural hemorrhage after surgery to repair a SABR related perforated gastric ulcer).  

**Reference:**  
37. In a recent Phase I dose escalation trial of SBRT in low-risk and intermediate-risk prostate cancer (Zelefsky, et. al.), what was the 5-year PSA failure for patients treated to a dose of 32.5 Gy in 5 fx?

   A. 0%
   B. 5%
   C. 15%
   D. 25%

**Key:** C

**Rationale:**
The 5-year PSA failure for patients treated to 32.5 Gy in 5 fractions was 15%.

**Reference:**

38. Which laboratory test abnormality is MOST frequently associated with a pancreatic adenocarcinoma?

   A. CEA
   B. CA 19-9
   C. CA 27.29
   D. AFP

**Key:** B

**Rationale:**
CA 19-9 elevation is most frequently associated with pancreatic adenocarcinoma. It is elevated in approximately 70% of pancreatic cancer patients.

**Reference:**
39. For which of the following clinical scenarios would liver SBRT be a recommended treatment?

A. Resectable extrahepatic cholangiocarcinoma  
B. 7 cm HCC tumor invading the portal vein with Child Pugh A6 cirrhosis  
C. Metastatic rectal cancer with a solitary 5 cm liver metastasis invading the duodenum  
D. Metastatic colorectal cancer with 3 subcentimeter liver metastases, and bilateral lung metastases

**Key:** B

**Rationale:**  
Option A is incorrect as the tumor is invading the bowel, and SBRT is not recommended in this situation. Option B is correct as the patient is CP A and eligible for SBRT. Venous tumor involvement is not a contraindication for SBRT. RTOG1112 specifically includes these patients, as often few other options for liver directed therapy can be offered to these patients. Option C is incorrect as the recommended therapy for a surgical candidate with resectable cholangiocarcinoma is surgical resection. Option D is incorrect, as the patient has widely metastatic colorectal cancer, with only a small burden of disease in the liver.

**Reference:**  
RTOG1112 Protocol (Inclusion Criteria).  
NCCN Guidelines for Extrahepatic Cholangiocarcinoma.

40. A patient undergoes radical inguinal orchiectomy for an 8cm right testicular seminoma. Pathology showed invasion of rete testes and LVSI; and there was no nodal involvement on scans; serum markers returning to normal levels after surgery. What is the recommended RT technique?

A. 30Gy with right sided “dog leg” field  
B. 30Gy with para-aortic only field  
C. 20Gy with right sided “dog leg” field  
D. 20Gy with para-aortic only field

**Key:** D

**Rationale:**  
The standard treatment for patients with Stage I Seminoma with no history of previous pelvic surgery is 20Gy in 10 fractions to the para-aortic fields.

**Reference:**  
41. What test is generally used to compare the mean of small samples?

A. T-test  
B. F-test  
C. Fisher Z-test  
D. Chi-square test

Key: A

Rationale:  
When one or the other of the sample sizes is small, as is often the case in practice, the Central Limit Theorem does not apply. If the distribution with small sample size is normal or approximately normal, then the Student’s t distribution and associated statistics can be used.

Reference:  

42. A patient undergoes an orchiectomy for a stage I pure seminoma and then elects to undergo treatment with chemotherapy. What is the recommended chemotherapy?

A. Single agent cisplatin  
B. Bleomycin, etoposide, and cisplatin  
C. Rituximab, cyclophosphamide, doxorubicin, and vincristine  
D. Single agent carboplatin

Key: D

Rationale:  
The NCCN recommends use of single agent Carboplatin in patients treated with chemotherapy for Stage 1 pure seminoma. A combination of Bleomycin, etoposide, and cisplatin is used in patients with stage II or III disease. A combination of rituximab, cyclophosphamide, doxorubicin, vincristine, alone with prednisone is often used for non-Hodgkin lymphoma.

Reference:  
43. Prospective randomized data from the TAILORx trial found no benefit to chemotherapy in which of the following ER-positive patients?

A. 53yo with pT1-T2N1 low Oncotype RS (< 11)
B. 43yo with pT1-T2N0 intermediate Oncotype RS (11-26)
C. 58yo with pT1-T2N0 intermediate Oncotype RS (11-26)
D. 65yo with pT1-T2N0 high Oncotype RS (> 26)

Key: C

Rationale: The trial did not include node-positive patients and a small benefit to chemo was found in patients <50yo with intermediate score.


44. Which partial breast dose fractionation scheme yielded worse cosmesis as compared to whole breast RT?

A. 30 Gy in 5 non-consecutive fx
B. 40.05 Gy in 15 fx
C. 32 Gy in 8 fx b.i.d.
D. 38.5 Gy in 10 fx b.i.d.

Key: D

Rationale: The Canadian RAPID trial has reported worse cosmesis with 38.5 Gy delivered in 10 fractions b.i.d. as compared to whole breast RT using conventional fractionation +/- a boost. By contrast, the Florence trial (30 Gy in 5 non-consecutive fractions with external beam) and the IMPORT Low trial (40.05 Gy in 15 fractions with external beam) were cosmetically superior to whole breast RT. The GEC-ESTRO trial (32 Gy in 8 fractions b.i.d. with multi-catheter interstitial brachytherapy) was not different in cosmetic outcome as compared to whole breast RT.

45. A 90-year-old patient with a history of pT3bN0M0 renal cell carcinoma presents 5 years later with a biopsy proven lung metastasis from his primary kidney cancer. What is the best option?

A. Conventionally fractionated radiation therapy  
B. Chemotherapy regimen that includes cisplatin and SFU  
C. Immunotherapy  
D. SBRT  

**Key:** C & D  
**NOTE:** This item was double-keyed for scoring purposes upon post-exam statistical item analysis.  

**Rationale:**  
For oligometastatic RCC patients, particularly those presenting >1 year (metachronous metastasis) after their nephrectomy and with limited number of metastasis, the data supports local therapy including surgery or SBRT.  

**Reference:**  

46. Vismodegib may be used to treat metastatic or locally advanced basal cell carcinoma. What is the mechanism of action of vismodegib?

A. B-Raf inhibitor  
B. Programmed death 1 (PD-1) inhibitor  
C. Smoothen homologue (SMO) inhibitor  
D. Programmed death-ligand 1 (PD-L1) inhibitor  

**Key:** C  

**Rationale:**  
Almost all basal cell carcinomas contain genetic alterations in the hedgehog signaling pathway, resulting in aberrant pathway activation and uncontrolled proliferation of basal cells. Most commonly, these alterations cause loss of function of patched homologue 1 (PTCH1), which normally acts to inhibit the signaling activity of smoothened homologue (SMO), a seven-transmembrane protein. Vismodegib is a small-molecule inhibitor of SMO. Vi-SMO-degib.  

**Reference:**  
47. In the 2014 Early Breast Cancer Trialists’ Collaborative Group (EBCTCG) meta-analysis of post-mastectomy trials, what was the impact of RT in women with 1-3+ nodes who underwent an axillary dissection and received systemic therapy?

A. It was detrimental in this population
B. It yielded no benefit
C. It improved locoregional control only
D. It improved locoregional control and breast cancer specific survival

Key: D

Rationale:
In the EBCTCG meta-analysis, the improvement in breast cancer mortality for post-mastectomy radiotherapy was an impressive 8%, even for those patients with 1-3 positive nodes who underwent an axillary dissection and systemic therapy. This highlights the value of post-mastectomy radiotherapy, even for those women with 1-3 positive nodes, although some question of its relevance to the era of modern systemic therapy remains.

Reference:

48. What is the most common site of urethral cancer in men?

A. Bulbomembranous urethra
B. Penile urethra
C. Prostatic urethra
D. Vesicular urethra

Key: A

Rationale:
The most common location of urethral cancer in males is the bulbomembranous urethra. The distal penile urethra is a less common location of urethral cancer.

Reference:
49. According to the updated ASTRO APBI consensus statement, what delivery technique was recommended to be restricted to the context of a prospective registry or clinical trial?

A. Balloon brachytherapy  
B. External beam RT  
C. Interstitial brachytherapy  
D. Low energy x-ray IORT

Key: D

Rationale:
A new key question was included to address which patients may be considered for intraoperative PBI. Per the consensus statement, patients should be informed that risk for IBTR was higher with IORT, electron beam IORT should be restricted to women with invasive cancer considered “suitable” by criteria, and low energy x-ray IORT should be used within a prospective registry or clinical trial and restricted to women with invasive cancer considered “suitable” by criteria.

Reference:

50. Which bladder cancer histology is derived from the embryological remnant of the urachus?

A. Transitional Cell  
B. Adenocarcinoma  
C. Squamous cell Carcinoma  
D. Pheochromocytoma

Key: B

Rationale:
Adenocarcinoma of the bladder is most often derived from embryonal remnant of the Urachus and occur in the dome of the bladder. Transitional cell carcinomas accounts for 92% of all bladder cancers and are often associated with smoking or exposure to aromatic amines, organic solvents, or arylamines. Squamous cell carcinomas are often associated with chronic irritation (Schistosoma haematobium, long term self-catheterization, chronic UTI). Pheochromocytomas are rare histologies found in bladder cancer.
51. In the GOG-258 randomized trial of advanced endometrial carcinoma, what was the approximate 5-year incidence of pelvic/paraaortic nodal recurrence in the chemotherapy alone arm?

A. 10%
B. 20%
C. 30%
D. 40%

Key: B

Rationale:
Chemoradiotherapy was associated with a lower 5-year incidence pelvic and/or paraaortic lymph-node recurrence (11% vs. 20%; hazard ratio, 0.43; 95% CI, 0.28 to 0.66) than with chemotherapy alone. However, standard chemotherapy resulted in better severe acute toxicity, a higher rate of completion of treatment, a trend towards better distant control, and equivalent RFS.

Reference:

52. The STAMPEDE trial (Lancet 2018) titled “Radiotherapy to the primary tumor for newly diagnosed, metastatic prostate cancer (STAMPEDE): a randomized controlled Phase 3 trial” showed OS benefit for the addition of prostate radiation to standard therapy for low-burden metastatic prostate cancer patients. How was low burden disease defined?

A. Three or fewer metastases
B. Three or fewer vertebral metastases and no visceral metastasis
C. Bone metastasis only
D. Fewer than three bone metastases or one nodal metastasis

Key: B

Rationale:
High metastatic burden of disease in STAMPEDE trial was defined as “four or more bone metastases with one or more outside the vertebral bodies or pelvis, or visceral metastases, or both”; all other assessable patients were considered to have low metastatic burden.

Reference:
53. The figure below is a Kaplan-Meier curve of patient OS. The “+” symbols correspond to:

A. patients’ death.
B. censored patients.
C. patients that returned for a follow-up visit.
D. when patients enrolled in the study.

Key:  B

Rationale:
A Kaplan-Meier (KM) survival curve is a plot of patient survival over time. Steps/drops in the line correspond to instances when one or more patients experienced the event of interest (e.g., death) at a given follow-up time. The “+” symbols correspond to participants that were censored because they did not experience the event of interest during the study period. Censoring can occur for a variety of reasons such as patients being lost to follow up or the study terminating before patients experienced the event of interest.

Reference:
54. In the AJCC 8th edition for breast cancer, what feature is included in the **prognostic** stage grouping?

   A. Lymphovascular invasion (LVI)
   B. Ki-67 index
   C. Extracapsular extent (ECE)
   D. Progesterone receptor (PR) status

**Key:** D

**Rationale:**
The new factors incorporated into Prognostic Stage Grouping include: ER status, PR status, H2N status, grade, and Oncotype RS.

**Reference:**

55. On the Collaborative Ocular Melanoma Study (COMS), what were the MOST commonly used sources for eye plaques?

   A. $^{125}$I and $^{103}$Pd
   B. $^{137}$Cs and $^{103}$Pd
   C. $^{60}$Co and $^{131}$Cs
   D. $^{90}$Y and $^{60}$Co

**Key:** A

**Rationale:**
The American Association of Physicists in Medicine (AAPM) and American Brachytherapy Society (ABS) review indicates the most commonly used prescription dose for ocular melanoma eye plaques is 85 Gy at 5 mm depth when using $^{125}$I and $^{103}$Pd sources. $^{60}$Cobalt is used for Gamma Knife. $^{137}$Cesium is more often used for low dose rate cervical brachytherapy. $^{131}$Cesium is more often used for low dose rate prostate cancer brachytherapy. $^{90}$Yttrium is more often used for liver radioembolization.

**Reference:**
56. Based on RTOG 9802, which patient with a low-grade glioma would gain an OS benefit from the addition of chemotherapy after radiation?

A. 15-year-old  
B. 25-year-old  
C. 35-year-old  
D. 45-year-old

**Key:** D

**Rationale:**
RTOG 9802 randomized high risk low grade glioma patients, defined as either >40 years only or subtotal resection, to either radiation versus radiation followed by PCV. The updated analysis found both a progression free survival benefit and overall survival benefit.

**Reference:**

57. In evaluation of potential risk of liver decompensation after liver SBRT, the ALBI score incorporates:

A. albumin alone.  
B. albumin and bilirubin.  
C. albumin, bilirubin, and INR.  
D. albumin, bilirubin, INR and ascites.

**Key:** B

**Rationale:**
ALBI = (log₁₀ bilirubin × 0.66) + (albumin × -0.085), where bilirubin is in μmol/L and albumin in g/L.

**FACTS & FIGURES**

<table>
<thead>
<tr>
<th>ALBI Score</th>
<th>Grade</th>
<th>Median survival</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤-2.60</td>
<td>1</td>
<td>18.5-85.6 months</td>
</tr>
<tr>
<td>&gt;-2.60 to ≤-1.39</td>
<td>2</td>
<td>5.3-46.5 months</td>
</tr>
<tr>
<td>&gt;-1.39</td>
<td>3</td>
<td>2.3-15.5 months</td>
</tr>
</tbody>
</table>

**Reference:**
58. In the START B Trial, which endpoint was NOT superior in the hypofractionation arm?

A. Telangiectasia
B. Breast edema
C. Local recurrence
D. Breast shrinkage

Key: C

Rationale:
In the START B trial local control, overall survival, breast induration, arm edema, and shoulder stiffness were not different between the two arms, while telangiectasia, breast edema, and breast shrinkage favored the hypofractionation arm of 40.05 Gy in 15 fractions.

Reference:

59. When the outcome of a clinical trial is the event rate (e.g., %), the absolute risk reduction (ARR) between the control arm and the treatment arm is defined as the:

A. sum of the event rate of the control and the treatment arm.
B. difference between the event rate of the control and the treatment arm.
C. difference between the event rate of the control and the treatment arm divided by the event rate of the control arm.
D. difference between the event rate of the control and the treatment arm divided by the event rate of the treatment arm.

Key: B

Rationale:
The definition of ARR is the difference between the event rate of the control arm and that of the treatment arm.

Reference:
60. What is the AJCC 8th edition staging for a patient with a 3 cm tonsil HPV+ squamous cell carcinoma primary and multiple small nodes in the retropharynx and ipsilateral levels II and III, with a PET/CT negative for contralateral neck adenopathy and distant metastases?

A. T1N1M0  
B. T1N2bM0  
C. T2N1M0  
D. T2N2bM0

**Key:** C

**Rationale:**
In AJCC 8th edition, an HPV positive oropharynx cancer with a primary tumor >2cm is a T2 and multiple ipsilateral nodes is N1. The T2N2bM0 designation would be correct for an HPV negative tonsil primary with this presentation.

**Reference:**

61. After definitive chemoradiation for treatment of anal cancer, what is the minimum length of time (months) to wait before performing a biopsy on a persistent, but responding mass?

A. 1  
B. 3  
C. 6  
D. 12

**Key:** C

**Rationale:**
Anal squamous cell carcinoma can continue to regress for up to 6 months. Data from the ACT II study demonstrate this. Counting from the beginning of therapy, the complete response rate at 11 weeks was 52%, at 18 weeks was 71%, and at 26 weeks was 78%. Furthermore, 72% of the patients who did not have a complete response at the first assessment did have a complete response at the third.

**Reference:**
62. In the 2016 series by Tao et. al. on radiation for intrahepatic cholangiocarcinoma, what was the 3-year local control rate for tumors treated with high BED RT?

A. 36%
B. 52%
C. 78%
D. 94%

**Key:** C

**Rationale:**
The 3-year local control rate for high BED (>80.5 Gy) patients was 78%.

**Reference:**

63. In Grade 1-2 endometrioid carcinoma, what is the MOST common method to specify the target volume in single-modality postoperative vaginal cylinder brachytherapy?

A. Entire vagina
B. Entire vagina excluding the distal 1 cm
C. Vaginal cuff up to 2.5 cm in length
D. Proximal 4 cm length

**Key:** D

**Rationale:**
While the individual approaches vary, the most commonly used in U.S. prescription is one specifying a fixed vaginal length. Four centimeters length has been reported to be the most prevalent in practice. It is unclear if treating total or near-total vaginal length improves outcomes, but it increases the probability of side effects.

**Reference:**
64. For a patient with locally advanced esophageal cancer endoscopically visualized at 20 cm from the incisors, which of the following diagnostic tests is NOT indicated?

A. Bronchoscopy  
B. Laparoscopy  
C. PET-CT  
D. Endoscopic ultrasound

**Key:** B

**Rationale:**
20 cm from the incisors indicates that this is an upper esophageal cancer, proximal to the carina (which is typically at around 25cm). The possibility of fistula should be ruled out via bronchoscopy. PET-CT and EUS are routinely indicated for staging of esophageal cancer. Laparoscopy would not routinely be indicated for proximal esophageal cancer.

65. On RTOG 9804, a randomized trial of RT in low risk DCIS, what outcomes did RT yield?

A. No benefit from RT  
B. Improvement in local control  
C. Improvement of local control and mastectomy-free survival  
D. Improved local control, mastectomy-free survival, and OS

**Key:** B

**Rationale:**
There was no significant difference in mastectomy rates or overall survival.

**Reference:**
66. Which statistic is used to estimate agreement between measurements for categorical data (e.g., agreement between radiologists for determining the presence of pulmonary embolism on a CT scan)?

A. Kappa statistic
B. Intraclass correlation coefficient
C. Bland-Altman plot
D. Pearson correlation coefficient

**Key:** A

**Rationale:**
The kappa statistic is the only listed option that estimates agreement for categorical data. The kappa statistic is an estimate of the observed agreement (e.g., between radiologists) compared to the agreement that is expected by chance. Kappa can be estimated using the following equation (Wassertheil-Smoller and Smoller 2015):

\[ Kappa = \frac{\text{Proportion observed agreement} - \text{Proportion agreement by chance}}{1 - \text{Proportion agreement by chance}} \]

**Reference:**

67. What were the results of RTOG 1016 and the De-ESCALaTE trials that randomized patients with HPV+ oropharyngeal squamous cell carcinoma to concurrent cisplatin/RT vs concurrent cetuximab/RT?

A. Concurrent cisplatin/RT had improved OS
B. Concurrent cetuximab/RT was non-inferior to cisplatin/RT
C. Both arms had similar locoregional control
D. Cetuximab/RT was less toxic than cisplatin/RT

**Key:** A

**Rationale:**
For patients with HPV-positive oropharyngeal carcinoma, radiotherapy plus cetuximab showed inferior overall survival and progression-free survival compared with radiotherapy plus cisplatin in the indicated randomized control trials. Compared with the standard cisplatin regimen, cetuximab showed no benefit in terms of reduced toxicity, but instead showed a significant detriment in terms of tumor control. Cisplatin and radiotherapy should be used as the standard of care for HPV-positive low-risk patients who are able to tolerate cisplatin.

**Reference:**
68. What is the AJCC stage grouping for a 2.5 cm squamous cell carcinoma of a labium majus, metastatic to one inguinal and one pelvic lymph node?

A. IIIA
B. IIIB
C. IVA
D. IVB

Key: D

Rationale:
In vulvar cancer, pelvic lymph node metastases are considered distant sites and their involvement at diagnosis signifies poor overall prognosis.

Reference:

69. What was the approximate median OS (years) of patients with 1p19q codeleted gliomas following PCV and sequential RT on RTOG 9402?

A. 5
B. 10
C. 15
D. 20

Key: C

Rationale:
RTOG 9402 randomized patients with anaplastic oligodendroglioma to radiation alone versus PCV plus radiation, and found that among patients with codeleted tumors, PCV+RT resulted in median survival of 14.7 years (compared to 7.3 years with RT alone in this subgroup).

Reference:
70. What treatment is recommended for stage IIA squamous cell carcinoma of the vagina?

A. EBRT + brachytherapy
B. Brachytherapy alone
C. Wide local excision
D. Laser ablation

Key: A

Rationale: For primary vaginal cancers extending outside of the vaginal wall, as in stage II, organ-sparing surgery is generally not feasible. Instead of exenterative procedures, which are possible, primary radiotherapy is most often used. The radiotherapy program includes external beam radiotherapy to the pelvis to address subclinical disease spread.


71. In the randomized TIME-C (RTOG 1203) trial comparing IMRT vs 3D for pelvic radiotherapy after hysterectomy, what was LESS frequent in the IMRT arm?

A. Use of urinary tract analgesics
B. Use of anti-diarrheals
C. Witnessed emesis
D. Silver sulfadiazine application

Key: B

Rationale: Patients with cervical and endometrial cancer who received pelvic radiation postoperatively were stratified by dose (45 or 50.4 Gy), use of chemotherapy (none or 5 cycles of weekly cisplatin at 40 mg/m2), and disease site, and then randomly assigned to standard 4-field radiation or IMRT. The primary endpoint was a change in acute gastrointestinal (GI) toxicity from baseline to 5 weeks measured by the bowel domain of Expanded Prostate Cancer Index Composite (EPIC). 20.4% of women on the standard RT arm took 4 or more antidiarrheal medications daily, as compared to 7.8% of women on the IMRT arm (P = 0.04). GI toxicity was not different between 2 arms and 4-6 weeks after RT completion.

72. In NSABP B-27, a trial of neoadjuvant chemotherapy, the addition of docetaxel to doxorubicin/cyclophosphamide improved the rate of pathologic CR from 13.7% to which percent?

A. 14%
B. 26%
C. 40%
D. 60%

Key: B

Rationale:
The rate of pCR in NSABP B-27 was 13.7% with AC and 26.1% with AC followed by docetaxel. Later studies clarified that the biological subtype was strongly associated with the rate of pCR.

Reference:

73. According to the results of the EMBRACE prospective study on cervical HDR brachytherapy, what D2cc rectal dose (EQD2) total dose limit was proposed to reduce the risk of grade 2 or worse proctitis?

A. <60 Gy
B. <65 Gy
C. <70 Gy
D. <75 Gy

Key: B

Rationale:
Dose to the most exposed 2 cm³ of the rectum ("D2cc") correlated with moderate and severe rectal toxicity of radiation. While there is no clear lower dose threshold, there appears to be a steep improvement in side effect rates when total D2cc (combined EBRT and brachytherapy) is kept below 65 Gy. Additional DVH scrutinization, including evaluating rectal D0.1cc is necessary in brachytherapy practice.

Reference:
Mazeron, et al. Dose–volume effect relationships for late rectal morbidity in patients treated with chemoradiation and MRI-guided adaptive brachytherapy for locally advanced cervical cancer: Results from the prospective multicenter EMBRACE study. Radiotherapy and Oncology 120:3; p412-419.
74. Which of the following molecular abnormalities is MOST consistent with a sporadic endometrial cancer?

A. MLH1 promoter methylation
B. MSH2 loss of expression
C. PMS2 loss of expression
D. EPCAM deletion

Key: A

Rationale:
Lynch syndrome-related cancers commonly do not demonstrate hypermethylation of the MLH1 promoter

Reference:

75. What adjuvant systemic therapy should a patient with ER-positive isolated locoregional recurrent breast cancer should undergo per the CALOR trial?

A. Hormonal therapy alone
B. Chemotherapy alone
C. Chemotherapy and hormonal therapy
D. No additional systemic treatment

Key: A

Rationale:
The trial found that ER- patients should have chemotherapy and ER+ patients should have hormonal therapy alone (no benefit from chemo).

Reference:
76. Which of the following is the preferred treatment regimen for a 25-year-old female with an RB1 germline mutation treated with breast-conserving surgery and SLNB revealing t2N0 invasive ductal carcinoma?

A. Whole breast radiotherapy with hypofractionation  
B. Whole breast radiotherapy with conventional fractionation  
C. Partial breast radiotherapy  
D. Completion mastectomy

**Key:** D

**Rationale:**
Patients with germline RB mutation have a high risk of induction of cancers such as osteosarcoma in the radiotherapy field. In this young patient with a highly curable breast cancer it would be preferable to avoid radiotherapy. Also, patients this young are listed in the “unsuitable” category in the ASTRO APBI consensus.

**Reference:**  

77. Which of the following is considered a limitation of the Intergroup 0116 (“MacDonald”) trial of postoperative chemoradiotherapy for gastric cancer?

A. Patients were not required to have margin-negative resection  
B. No quality assurance for radiotherapy was performed  
C. The chemotherapy regimen was not standardized  
D. The extent of nodal dissection was not standardized

**Key:** D

**Rationale:**
Patients were not required to have a D2 nodal dissection, and the majority had only a D0 dissection, raising the question of whether chemoRT was primarily “compensating” for inadequate surgery. Only patients with R0 resections were eligible, the chemotherapy regimen was standardized, and quality assurance reviews of radiotherapy plans were performed.

**Reference:**  
78. What is the absolute four-year OS benefit of docetaxel when added to long-course ADT + RT for patients with high-risk localized prostate cancer?

A. None  
B. 5%  
C. 10%  
D. 15%

**Key:** B

**Rationale:**
Patients treated with docetaxel in addition to androgen suppression therapy and radiation therapy had a 4-year overall survival benefit of 93%, compared to 89% (p=0.034) for patients treated without chemotherapy.

**Reference:**

79. 50-year-old man with T2N2M0 EBV+ NPC is treated with 70 Gy radiation with concurrent cisplatin and has complete resolution of disease. What is the MOST appropriate next step in management?

A. No further treatment; PET-CT in 12 weeks  
B. Consolidative biotherapy/immunotherapy  
C. No further treatment; CT of the neck in 6 weeks  
D. Consolidative cisplatin-based systemic chemotherapy

**Key:** D

**Rationale:**
Although controversial, at present, the optimal treatment for advanced nasopharyngeal carcinoma is concurrent chemoradiation and adjuvant chemotherapy, on the basis of meta-analysis. This would be particularly true for this patient, presenting with both advanced disease and nodal involvement.

No adjuvant chemo is category 2B per NCCN guidelines. Induction chemotherapy may be used instead of consolidative chemotherapy, but was not given in this scenario.

**Reference:**
80. In the Princess Margaret Cancer Center re-evaluation of ipsilateral RT for T1-T2N0-N2b tonsillar carcinomas, what were the contralateral neck failure rates for HPV+ and HPV- tumors, respectively, at 5 years?

A. 2% and 3%
B. 2% and 9%
C. 8% and 3%
D. 8% and 9%

Key: A

Rationale:
This trial confirmed a very low rate of contralateral neck failure even in patients with up to N2b nodal status with ipsilateral radiation therapy, regardless of HPV status and even with only 2% of these patients receiving concurrent chemotherapy.

Reference:

81. In the GOG-249 randomized trial of patients with high-intermediate and high risk early stage endometrial cancer, which of the following was associated with the experimental (brachytherapy and chemotherapy) arm?

A. Improved OS
B. Improved nodal relapse rate
C. Worse acute toxicity
D. Less fatigue

Key: C

Rationale:
GOG 249 enrolled 610 patients randomly assigned to the typical pelvic irradiation or the combination of chemotherapy and vaginal brachytherapy. Most patients had the G1-2 endometrioid histology. Standard EBRT resulted in lower nodal relapse rate, better acute toxicities, and lower patient-reported fatigue levels while maintaining the same OS and RFS as the experimental treatment.

Reference:
82. Lobular carcinoma characteristically stains negative for:

A. estrogen receptor.
B. GATA3.
C. E-cadherin.
D. progesterone receptor.

Key:  C

Rationale:
E-cadherin is a cell-cell adhesion molecule that is classically absent in lobular carcinoma and serves as a reliable marker in the differentiation between lobular and ductal carcinoma.

Reference:

83. What type of study design compares a treatment group to a control group from a previous study?

A. Cross-over study
B. Prospective cohort study
C. Historical controlled study
D. Cluster randomized controlled study

Key:  C

Rationale:
A historical controlled trial is a study where the treatment group is compared to control-group data that were previously collected. In all of the other listed study designs treatment groups and control groups are concurrently enrolled.

Reference:
84. According to the AJCC 8th edition for head and neck staging, what is the pathologic nodal stage for an HPV-squamous cell carcinoma metastasis in a single ipsilateral lymph node, 2 cm, with extracapsular extension?

A. N1b  
B. N2a  
C. N2c  
D. N3b

**Key:** B

**Rationale:**
In AJCC 8th edition, extracapsular extension in excised lymph nodes raises the N stage. A single cervical lymph node 3 cm or less in size is N1, but with extracapsular extension is N2a.

**Reference:**

85. What is an appropriate RT dose for treatment of localized Kaposi sarcoma?

A. 12 Gy in 2 fx  
B. 24 Gy in 12 fx  
C. 50 Gy in 20 fx  
D. 60 Gy in 30 fx

**Key:** B

**Rationale:**
While the literature is varied and limited on use of radiation in the treatment of Kaposi sarcoma, a number of different regimens have been reported including studies using 6 Gy x 1 and 8 Gy x 1 (Yildiz et al 2006) and a prospective randomized study of 24 Gy in 12 fractions vs 20 Gy in 5 fractions (Singh et al 2008).

**Reference:**
86. A patient with a history of adenoid cystic carcinoma of the hard palate develops pain and sensitivity over the right mid-face and cheek. Which foramen is MOST likely to show expansion on bone-windows of a CT?

A. Foramen ovale  
B. Foramen lacerum  
C. Foramen rotundum  
D. Stylomastoid foramen

**Key:** C

**Rationale:**
Innervation of the mid-face and cheek is via the maxillary division of the trigeminal nerve (CN V2) which enters the skull base at foramen rotundum. The mandibular division of the trigeminal nerve (V3) enters the skull base at foramen ovale. The facial nerve (CN VII) enters the skull base at the stylomastoid foramen. The major branches of the cranial nerves do not pass through foramen lacerum; the nerve of the pterygoid canal passes through foramen lacerum.

**Reference:**

87. What GTV dosimetric factor is MOST closely correlated with an increased risk of local relapse in patients receiving single fraction spine SBRT?

A. $D_{\text{min}} < 14 \text{ Gy}$  
B. $D_{95} < 12 \text{ Gy}$  
C. Mean dose $< 14 \text{ Gy}$  
D. $D_{98} < 16 \text{ Gy}$

**Key:** A

**Rationale:**
Two studies have correlated GTV Dmin as the factor associated with local control for patients receiving SSRS. Bishop and colleagues reported a GTV Dmin of 14 Gy in a single fraction as being correlated with relapse risk, which was similar to an older study by Lovelock and colleagues that showed 15 Gy was an important factor.

**Reference:**
88. Which of the following is TRUE regarding vaginal cylinder brachytherapy?

A. Radiation tolerance of the distal vagina is the highest  
B. Rigid vaginal dilator use is not feasible  
C. Treatment length predicts toxicity  
D. Smallest cylinder diameter is preferable

Key: C

Rationale:
Women treated with postoperative vaginal brachytherapy are at risk of late vaginal mucosal toxicity (vaginal dryness, shortening, dyspareunia). In addition to the total radiation dose, an increase in toxicity rate has been observed with increased length of the vagina being treated. The risk of severe vaginal stenosis may be mitigated by regular dilator use, with rigid devices being the most common type.

Reference:

89. What is the recommended prescription dose range when using 1 – 5 fraction stereotactic radiation to treat functioning pituitary adenomas?

A. 2 - 12 Gy  
B. 20 - 35 Gy  
C. 45 - 54 Gy  
D. 55 - 65 Gy

Key: B

Rationale:
For functioning pituitary adenomas, doses of 20 to 35 Gy are used with various stereotactic radiosurgery (SRS) or fractionated stereotactic radiotherapy (FSRT) techniques that prescribe to the 50% to 80% isodose line. Non-functioning pituitary adenomas can be treated to a lower dose.

Reference:
90. According to the IMRT contouring guidelines for treating intact cervix squamous cell carcinoma when there is no vaginal involvement, what proportion of the vagina is required to be included in the CTV?

A. 25%
B. 50%
C. 66%
D. 100%

Key: B

Rationale:
According to the published contouring guidelines, vaginal coverage in the CTV for intact cervix is as follows:

1) no vaginal extension = upper 1/2 of the vagina
2) upper vagina involved = proximal 2/3 of the vagina
3) extensive vaginal involvement = the entire vagina

Reference:

91. In a double-blind Phase III clinical trial:

A. both investigators and participants do not know the treatment.
B. the investigators know the treatment, but the participants do not.
C. the participants know the treatment, but the investigators do not.
D. both investigators and participants know the treatment.

Key: A

Rationale:
In a double-blind clinical trial, neither the persons receiving the treatment (patients) nor the study investigators know the identity of the treatment assignment. The primary purpose of blinding is to reduce bias.

Reference:
92. What is the correct interpretation of hazard ratio (HR)?

A. HR = hazard in the control group / hazard in the intervention group
B. An HR of 0.5 means that twice as many patients in the treatment group are experiencing an event compared to the control group
C. An HR of 1.0 means that at any particular time the event rates are the same for both groups
D. An HR of 2.0 means that at any particular time, half as many patients in the treatment group are experiencing and event compared to the control group

Key: C

Rationale:
Hazard ratio’s define the relationship between two interventions. When the HR is “1” there is no difference in the rate of occurrence between the two groups. **Hazard ratios are important statistical tools used for interpretation and application of clinical trial data.**

Reference:
“Clinical Trial Design and Methodology” ASCO online

93. In the recently published STAMPEDE trial, what was the absolute OS benefit observed with the addition of localized prostate RT to standard of care in patients with metastatic prostate cancer with a low metastatic burden?

A. No OS benefit
B. 4%
C. 8%
D. 12%

Key: C

Rationale:
Patients with a low metastatic burden of metastatic prostate cancer were observed to have a 3 year overall survival of 81% when treated with localized prostate radiation therapy and standard of care, compared to a 3 year overall survival of 73% when treated with standard of care alone.

Reference:
Radiotherapy to the primary tumour for newly diagnosed, metastatic prostate cancer (STAMPEDE): a randomised controlled phase 3 trial. The Lancet, 2353-2366.
94. The ARTIST trial compared postoperative chemoradiotherapy to postoperative chemotherapy in resected gastric cancer. On subset analysis, which of patients appeared to have a benefit to CRT and were further evaluated on a follow up study ARTIST 2?

A. Pathologically node-negative disease  
B. Pathologically node-positive disease  
C. Positive surgical margins  
D. Intestinal-subtype adenocarcinoma  

**Key:** B

**Rationale:**
The ARTIST trial did not meet its primary endpoint (to demonstrate an increase in disease-free-survival with the use of CRT). However, subset analysis of node-positive patients suggested that those patients may have improved outcomes with CRT, and this was the basis of ARTIST 2. ARTIST 2 (Park SH, ASCO abstract 2019) was limited to node-positive patients, and included both intestinal and diffuse subtypes.

**Reference:**

95. If EBRT boost were to be considered instead of an implant for cervical cancer, which of the following would be TRUE regarding the comparison of the brachytherapy and the EBRT treatment plans?

A. Faster dose fall-off with EBRT  
B. Higher mean tumor dose with brachytherapy  
C. Comparable maximum point dose  
D. Improved skin sparing with EBRT  

**Key:** B

**Rationale:**
Due to the fundamental physical properties of brachytherapy, implants are dosimetrically superior to any form of EBRT in cervical cancer. Notably, in brachytherapy, the areas of high inhomogeneity are located at the center of the target, which probably contributes to high clinical efficacy seen with the use of implants.

**Reference:**
96. What is the AJCC 8th edition staging for pT1-4aN1 cM0 bladder cancer?

A. IIIA
B. IIIB
C. IVA
D. IVB

**Key:** A

**Rationale:**
Patients with T1-4aN1M0 bladder cancer have Stage IIIA disease. Patients with T1-4aN2-3 bladder cancer have Stage IIIB disease. Patients with T4b or M1a disease have Stage IVA disease, and patients with M1b bladder cancer are diagnosed as having Stage IVB disease. It is important to note that while the 7th edition of the AJCC staging classified patients with node positive disease as having Stage IV disease, the 8th edition now includes node positive patients in Stage III.

97. In the IMPORT LOW Trial, what was the 5-year local relapse rate in women without high-risk factors (ER+, H2N-, grade 1-2, no LVI, negative lymph nodes)?

A. 1%
B. 4%
C. 8%
D. 12%

**Key:** A

**Rationale:**
The 1088 women in the IMPORT LOW Trial who had no high-risk factors had experienced a total of 10 local recurrences after receiving 40.05 Gy in 15 fx. This confirms data from the EORTC 22881 boost trial – namely that women over 50 with low to intermediate grade disease derived a very small benefit from the boost and highlights the viability of avoiding a boost in this population.

**Reference:**
98. Which of these options is NOT a standard treatment for locally advanced adenocarcinoma of the GE junction?

A. Definitive chemoradiotherapy to 50.4 Gy without surgery  
B. Preoperative chemoradiotherapy to 41.4 Gy followed by surgery  
C. Pre and post operative chemotherapy with surgery (no radiation)  
D. Surgery followed by chemotherapy and chemoradiotherapy to 45 Gy

**Key:** A

**Rationale:**
The RTOG 8501 trial, which established definitive concurrent chemoradiation as an effective treatment strategy for esophageal cancer, specifically excluded tumors with gastric involvement. The other three treatment options, which include surgery, are all supported by major randomized trials (CROSS trial, MAGIC trial, and MacDonald trial respectively).

99. Which of the following cranial nerves runs through the cavernous sinus?

A. II  
B. IV  
C. V3  
D. VII

**Key:** B

**Rationale:**
Cranial nerves III, IV, V1, V2, and VI run through the cavernous sinus.

**Reference:**

100. Per QUANTEC, what mean bilateral parotid dose that gives a < 50% risk of long-term salivary function < 25%?

A. 14 Gy  
B. 26 Gy  
C. 39 Gy  
D. 60 Gy

**Key:** This item was 0-weighted for scoring purposes upon post-exam statistical item analysis (did not count for or against candidate in calculation of test scores)

**Rationale:**
See the QUANTEC summary table.

**Reference:**
Marks, et al. Use of normal tissue complication probability models in the clinic, UROBP, 76(3 Suppl S10-S19), Mar 1, 1010.
101. What is the appropriate ordering of sample sizes for Phase I through IV clinical trials?

   A. Phase I < Phase II < Phase III < Phase IV
   B. Phase IV < Phase III < Phase II < Phase I
   C. Phase I < Phase IV < Phase III < Phase II
   D. Phase III < Phase II < Phase IV < Phase I

   **Key:** A

   **Rationale:**
   Phase I trials correspond to the earliest phase in the clinical trial process. These trials focus on assessing drug safety and dosage and are the smallest trials (tens of participants).
   Phase II trials are larger than phase I trials (tens to hundreds of participants) and focus on drug safety and efficacy. Phase III trials are large trials (hundreds to thousands of participants) that seek to confirm results from earlier studies and establish whether a treatment can be approved for general use.
   Phase IV trials are trials that occur after the treatment has been approved for use and often involves several thousand participants.

   **Reference:**

102. What is a feature of a meta-analysis?

   A. Combines data from a single source
   B. Increases type 2 error
   C. Only includes Phase 3 clinical trial data
   D. Increases sample size and power

   **Key:** D

   **Rationale:**
   Meta-analysis studies compile information from multiple sources (typically smaller studies). It is a statistical tool that is used to combine data from multiple studies. The goal is to create a single, more precise estimate of an effect. By amplifying the sample size, the compilation of data may make trends, observation and results more apparent.

   **Reference:**
103. What is the MOST likely cause of vocal cord fixation in patients with hypopharynx cancer?

A. Vocalis muscle invasion  
B. Jugular foramen invasion  
C. Cricoarytenoid joint/muscle invasion  
D. Recurrent laryngeal nerve involvement

Key: C

Rationale:
There are a number of mechanisms described that lead to vocal cord dysfunction and all involve the cricoarytenoid joint and or muscle: supraglottic carcinoma encasing the arytenoid from above with its fixation due to weight effect; glottic carcinoma involving the inferior paraglottic space and extending toward the cryco-arytenoid unit; glottic-subglottic carcinoma invading the crico-arytenoid joint, and wrapping around it; transglottic and infraglottic carcinoma with massive involvement of the crico-arytenoid unit and of the posterior crico-arytenoid muscle.

Reference:

104. What is the approximate anatomical landmark of the renal hilum?

A. T9/T10  
B. L1/L2  
C. L3/L4  
D. L5/S1

Key: B

Rationale:
Knowledge of the location of the kidney is important when designing radiation fields particularly for testicular cancer.

Reference:
105. What is the MOST common site of metastases from osteosarcoma?

   A. Liver
   B. Lung
   C. Lymph nodes
   D. Muscle

**Key:** B

**Rationale:**
Over 80% of metastases from osteosarcoma occur in the lungs.

**Reference:**

106. What did the results of the RTOG 90-01 study, which compared external field RT + brachytherapy versus pelvic chemoradiotherapy + brachytherapy, reveal?

   A. Extended field radiotherapy was better tolerated
   B. DFS was comparable between the arms
   C. Concurrent chemoRT had better survival
   D. Concurrent chemoRT only benefited distant control

**Key:** C

**Rationale:**
RTOG 90-01 compared EFRT+ brachytherapy with pelvic chemoradiotherapy + brachytherapy. The concurrent chemotherapy used was cisplatin and 5FU and it was only used in the whole pelvis arm. Chemoradiotherapy had benefits for OS (67 vs. 41%), DFS (61 vs. 46%), and decreased LRF (18 vs. 35%) and DM (20 vs. 35%).

**Reference:**
107. What is an appropriate method of therapeutic intensification for the post-operative radiotherapy treatment of inflammatory breast cancer?

A. A hypofractionated regimen
B. The use of daily bolus
C. An axillary boost
D. Inclusion of the contralateral IM chain

Key: B

Rationale:
There are two method of therapeutic intensification for the treatment of inflammatory breast cancer that appear to yield relatively good locoregional control. They include either the use of daily bolus or the hyperfractionated, accelerated dose-escalation regimen pioneered by MD Anderson.

Reference:

108. Which factor makes a patient a poor candidate for bladder preservation?

A. High grade
B. Good bladder function
C. Presence of hydronephrosis
D. Tumor size < 5 cm

Key: C

Rationale: Functional kidney is required for definitive chemoradiation.

Reference:
109. Which nerve is associated with referred otalgia in the setting of upper aerodigestive tract cancers?

A. Pharyngeal nerve of CN V
B. Posterior auricular nerve of CN VII
C. Jacobson nerve of CN IX
D. Great auricular nerve

Key: C

Rationale:
The Jacobson nerve, a branch of cranial nerve IX, directly innervates the ear but also has pharyngeal, lingual, and tonsillar branches to supply the posterior one-third portion of the tongue, tonsillar fossa/pillars, pharynx, eustachian tube, and parapharyngeal and retropharyngeal spaces. Pathologic processes that involve these areas can result in referred otalgia.

Reference:
Hansen and Roach, 2018, p 117, Springer International Publishing AG.

110. What is the MOST appropriate treatment for T1N2b squamous cell carcinoma of the lateralized oral tongue?

A. Radiation therapy with definitive intent
B. Induction chemotherapy followed by surgery
C. Radiation therapy and concurrent chemotherapy
D. Surgery and adjuvant therapy as indicated by pathology

Key: D

Rationale:
The standard treatment for a lateralized oral tongue cancer is primary surgery followed by adjuvant therapy as dictated by pathologic risk factors.

Reference:
111. What is a reasonable dose constraint for the penile bulb in a patient undergoing definitive EBRT for early stage prostate cancer?

A. $D_{\text{max}}$ of 50 Gy  
B. < 50% of the volume to 60 Gy  
C. < 50% of the volume to 65 Gy  
D. Mean dose < 52.5 Gy

**Key:** D

**Rationale:**
A $D_{\text{max}}$ of 50 Gy is a standard dose constraint for femoral heads in prostate XRT. < 50 % of the volume to 60 Gy is a rectal constraint for Prostate XRT. < 50 % of the volume to 65 Gy is a bladder constraint for Prostate Cancer. RTOG studies use a Mean <52.5 Gy for the penile bulb.

**Reference:**
RTOG 0126 Protocol: A PHASE III RANDOMIZED STUDY OF HIGH DOSE 3D-CRT/IMRT VERSUS.

112. What is the primary goal of a Phase IV trial?

A. Determine MTD  
B. Obtain FDA approval  
C. Post approval assessment of safety and effectiveness  
D. Investigate off-label indications

**Key:** C

**Rationale:**
The primary goal of a Phase I trial is to determine the recommended dose for future phase II studies.

**Reference:**
113. What is the recommended maximum dose to the optic apparatus in single fraction radiosurgery to result in ≤ 1% risk of radiation-induced optic neuropathy per NTCP modeling?

A. 7 Gy  
B. 10 Gy  
C. 12 Gy  
D. 15 Gy

**Key:** B

**Rationale:**
A recent study by Milano and colleagues as part of an AAPM working group evaluated the normal tissue complication probability (NTCP) of the optic apparatus in hypofractionated treatments. Based on their study, they recommended a Dmax < 10 Gy to keep the risk of RION at ~1%. The TG101 report suggests using a 0.2cm³ threshold of 8 Gy in 1 fraction.

**Reference:**

114. In the International Watch and Wait Database Study for rectal cancer, what was the rate of regrowth at 2 years?

A. 5%  
B. 15%  
C. 25%  
D. 35%

**Key:** C

**Rationale:**
This study included 1009 patients who received neoadjuvant treatment and were managed by Watch and Wait in the database from 47 participating institutes (15 countries). We included 880 (87%) patients with a cCR. Median follow-up time was 3.3 years (95% CI 3.1-3.6). The 2-year cumulative incidence of local regrowth was 25·2% (95% CI 22·2-28·5%), 88% of all local regrowth was diagnosed in the first 2 years, and 97% of local regrowth was located in the bowel wall. Distant metastasis were diagnosed in 71 (8%) of 880 patients. 5-year overall survival was 85% (95% CI 80·9-87·7%), and 5-year disease-specific survival was 94% (91·96%).

**Reference:**
115. What is recommended after tumor-reductive surgery for stage IIIA1 endometrioid ovarian carcinoma, metastatic to a single paraaortic lymph node?

A. Observation
B. Chemotherapy
C. Pelvic RT and concurrent chemotherapy
D. Extended field RT and concurrent chemotherapy

**Key:** B

**Rationale:**
Radiotherapy plays a limited role in the management of ovarian cancer with definitive intent. Systemic platinum-based chemotherapy is advised after cytoreduction. Focal radiotherapy is used for temporary palliation of symptoms in the recurrent setting.

**Reference:**

116. According to the 2019 NCCN guidelines, which patient does NOT need to be referred for a genetics evaluation?

A. A 52 year-old female diagnosed with a triple negative breast cancer
B. A 52 year-old male diagnosed with a triple positive breast cancer
C. A 52 year-old female with ER/PR+ breast cancer whose father had metastatic prostate cancer
D. A 52 year-old female with ER/PR+ breast cancer whose mother had breast cancer at age 65

**Key:** D

**Rationale:**
Patients under the age of 60 with triple negative breast cancer, all men, and any patient with a first degree relative with metastatic prostate cancer should undergo BRCA testing. In order for the 52-year-old woman to qualify for testing her, first or second degree relative should be under the age of 45 at diagnosis.

**Reference:**
NCCN guidelines Breast and/or Ovarian Cancer Genetic Assessment BR/OV-1.
117. The 10-year results of RTOG 91-11 showed that concurrent cisplatin+ RT resulted in the best larynx preservation rate. What was the rate of deaths not attributed to larynx cancer or treatment in the concurrent treatment arm?

A. 10%
B. 20%
C. 30%
D. 40%

Key: C

Rationale:
Concomitant cisplatin/RT significantly improved the larynx preservation rate over induction cisplatin/5-FU followed by RT (HR, 0.58; 95% CI, 0.37 to 0.89; p=0.0050) and over RT alone (p< 0.001). No difference in late effects was detected, but deaths not attributed to larynx cancer or treatment were higher with concomitant chemotherapy (30.8% vs 20.8% with induction chemotherapy and 16.9% with RT alone).

Reference:

118. Sinonasal undifferentiated carcinoma (SNUC) arises from which tissue?

A. Salivary glands
B. Notocord remnant
C. Olfactory epithelium
D. Schneiderian mucosa

Key: D

Rationale:
The Schneiderian mucosa lines the nasal cavity and paranasal sinuses. Schneiderian mucosa is of ectodermal derivation in contrast to the mucosal lining of the nasopharynx which is endodermally derived. SNUCs are a poorly differentiated carcinoma that arise from Schneiderian mucosa.

Reference:
119. What is the median survival for primary CNS lymphoma following WBRT alone?

A. 2 months  
B. 12 months  
C. 24 months  
D. 36 months

**Key:** B  

**Rationale:** While primary CNS lymphoma was historically treated with whole brain radiation alone given its extreme radiosensitivity, the majority of patients would recur within the first year resulting in poor median survivals around 1 year (Nelson et al, IJROBP 1992). The addition to chemotherapy to whole brain radiation was found to significantly improve disease-free survival and overall survival to >40 months (DeAngelis et al, JCO 1992). Thus, high-dose methotrexate-based chemotherapy has become an integral part of the treatment of primary CNS lymphoma.

**Reference:**

120. Following total thyroidectomy for papillary thyroid carcinoma, which of the following is an indication for radioactive iodine (RAI) therapy?

A. Multifocal disease  
B. High risk histologic subtypes  
C. Microscopically positive margins (R1)  
D. Postoperative unstimulated thyroglobulin levels > 5-10

**Key:** D  

**Rationale:** With an unstimulated postoperative thyroglobulin level >5-10, patients are at significant risk for reoccurrence, metastatic progression, and/or cause-specific morality.

**Reference:**
NCCN Thyroid carcinoma 1.2019
121. The PRIMARY management of moderate Graves’ ophthalmopathy is:

A. radiation.
B. surgery.
C. chemotherapy.
D. steroids.

Key: D

Rationale:
The initial treatment of Graves ophthalmopathy includes treatment and reversal of hyperthyroidism if present. The primary management of the local process of moderate Graves’ ophthalmopathy (orbitopathy) is high dose glucocorticoids. Rituxan can be used in patients that are steroid refractory. Radiation is often used after medical management has failed. Indications for surgery include progression despite other measures.

Reference:

122. Which histological variant is classified as a grade III meningioma?

A. Rhabdoid
B. Clear cell
C. Choroid
D. Atypical

Key: A

Rationale:
Grade III meningioma histologies include rhabdoid, papillary, and anaplastic. Grade II meningioma histologies include clear cell, choroid, and atypical.

Reference:
123. In what percentage of patients with squamous cell carcinoma of unknown primary of the head and neck does the addition of PET/CT to anatomic imaging help identify the primary site?

   A. 5%
   B. 15%
   C. 30%
   D. 45%

Key: C

Rationale:
Despite the known physiologic uptake of F18-fluorodeoxyglucose in the head and neck, initial retrospective reports suggested that the addition of PET and/or CT could depict small primary tumors in approximately 25% of patients who had previously received a diagnosis of squamous cell carcinoma of unknown primary (SCCUP) on the basis of anatomic neck images and, often, examination under anesthesia (EUA). Later prospective analysis demonstrated that the addition of PET and/or CT led to the detection of 29% more mucosal cancers after anatomic neck imaging and, in most patients, EUA suggested SCCUP.

Reference:

124. In the updated meta-analysis of chemotherapy in head and neck cancer (MACH-NC), what was the 5-year OS benefit of adding concurrent chemotherapy to RT?

   A. 3.4%
   B. 6.5%
   C. 9.6%
   D. 12.4%

Key: B

Rationale:
The updated MACH-NC analysis showed a 6.5% improvement in 5 year overall survival and a 3.4% improvement in 10 year overall survival resulting from the use of concurrent chemotherapy and radiotherapy verses radiotherapy alone as primary treatment for head and neck squamous cell carcinoma.

Reference:
125. In the PRODIGE study, which randomized patients to receive adjuvant gemcitabine or adjuvant FOLFIRINOX, what was the median overall survival (in months) among patients who received FOLFIRINOX?

A. 24
B. 36
C. 45
D. 54

**Key:** D

**Rationale:**
Adjuvant therapy with a modified FOLFIRINOX regimen led to significantly longer survival than gemcitabine among patients with resected pancreatic cancer, at the expense of a higher incidence of toxic effects. At a median follow-up of 33.6 months, the median disease-free survival was 21.6 months in the modified-FOLFIRINOX group and 12.8 months in the gemcitabine group (stratified hazard ratio for cancer-related event, second cancer, or death, 0.58; 95% confidence interval [CI], 0.46 to 0.73; P<0.001). The disease-free survival rate at 3 years was 39.7% in the modified-FOLFIRINOX group and 21.4% in the gemcitabine group. The median overall survival was 54.4 months in the modified-FOLFIRINOX group and 35.0 months in the gemcitabine group (stratified hazard ratio for death, 0.64; 95% CI, 0.48 to 0.86; P = 0.003). The overall survival rate at 3 years was 63.4% in the modified-FOLFIRINOX group and 48.6% in the gemcitabine group.

**Reference:**

126. In the RTOG 91-11 randomized trial for locally advanced larynx cancer, what was the 10-year rate of larynx preservation with concurrent chemoRT?

A. 92%
B. 82%
C. 72%
D. 62%

**Key:** B

**Rationale:**
The highest rate of larynx preservation was seen with concurrent therapy, followed by induction chemotherapy, and the lowest rate was seen with radiation monotherapy. There was very little difference between larynx preservation rates at 5 and 10 years, as most failures occurred within the first five-years.

**Reference:**
127. Which GBM patients were included on the EORTC 26062-22061 trial that found a survival benefit for temozolomide with concurrent short-course radiation (40 Gy in 15 fractions) compared to the same radiation regimen alone?

A. Patients at least 50 years old and ECOG 2 – 4
B. Patients at least 50 years old or ECOG 2 – 4
C. Patients at least 65 years old and ECOG 0 – 2
D. Patients at least 65 years old or ECOG 0 – 2

Key: C

Rationale:
The Perry et al. trial enrolled patients 65 years of age or older who had newly diagnosed glioblastoma and were deemed by their physicians not to be suitable to receive conventional radiotherapy (60 Gy in 30 fractions) in combination with temozolomide. Eligible patients had an ECOG performance status of 0, 1, or 2. Patients were randomized to receive either radiotherapy alone or radiotherapy plus concomitant and adjuvant temozolomide. The trial found that the addition of temozolomide improved median overall survival from 7.6 months to 9.3 months.

Reference:

128. In women with advanced or recurrent serous endometrial cancer, 30% of tumors will over-express:

A. EGFR.
B. HER2.
C. PDL1.
D. ROS1.

Key: B

Rationale:
In a multicenter, randomized phase II trial for patients with stage III or IV or recurrent HER2/neu-positive endometrial cancer, addition of trastuzumab to carboplatin-paclitaxel was well tolerated and increased progression-free survival. [https://ascopubs.org/doi/full/10.1200/JCO.2017.76.5966](https://ascopubs.org/doi/full/10.1200/JCO.2017.76.5966).

Reference:
129. What is the MOST common radiation dose for treatment of Graves’ ophthalmopathy?

A. 8 Gy in 1 fx  
B. 20 Gy in 5 fx  
C. 20 Gy in 10 fx  
D. 30 Gy in 15 fx  

**Key:** C

**Rationale:**
Radiation is often used after medical management has failed. The most common dose is 20Gy in 2Gy per fraction for 10 fractions. It was the treatment arm of a randomized control trial of orbital radiation (20Gy) versus sham radiation (0Gy) which had a statistically significant improvement with radiation (relative risk, RR 1.9, p =0.04)

**Reference:**


130. Per the Mahajan, et. al. (2017) randomized trial that compared post-operative SRS versus observation for completely resected brain metastases, what is the 12-month local relapse rate in the surgical cavity following resection alone?

A. 42%  
B. 57%  
C. 72%  
D. 87%  

**Key:** B

**Rationale:**
Based on a randomized study by Mahajan and colleagues, for patients receiving surgery alone, the 12-month freedom from local recurrence was 43%, which translates into a 57% risk of local relapse at 12 months compared to 28% in patients receiving postop stereotactic radiosurgery.

**Reference:**
131. What is the T-stage for a 5.5 cm squamous cell carcinoma of the cervix with no vaginal involvement, positive parametrial extension, and no mucosal bowel or bladder involvement?

A. T1b3  
B. T1b1  
C. T1b2  
D. T2b  

Key: D  

Rationale:  
Parametrial extension remains the indicator of stage IIB disease in both the AJCC 8th Ed. and FIGO staging rules for cervical cancer.  

Reference:  

132. Which of the following is the BEST recommendation for adjuvant RT for a 72 year-old female with a 1.8 cm, grade 3, triple negative breast cancer with a negative sentinel lymph node and a single close margin?

A. No adjuvant radiation is needed since she is over 70  
B. Re-excision followed by hypofractionated radiation without a boost  
C. Hypofractionated radiation to the whole breast with a tumor bed boost  
D. Hypofractionated radiation to the breast and low axilla  

Key: C  

Rationale:  
This is a triple negative breast cancer and was not included in the CALGB 9343 trial of women over the age of 70. There is no tumor on ink and thus re-excision is recommended. The lymph nodes were negative so the low axilla should not be intentionally targeted. Given that it is a high-grade triple negative a tumor bed boost is recommended.  

Reference:  
133. For a GE junction adenocarcinoma, sparing of which organ using IMRT can provide a survival benefit?

A. Stomach  
B. Liver  
C. Kidney  
D. Heart

**Key:** D

**Rationale:**
In a SEER analysis of esophageal cancer, on propensity score inverse probability of treatment weighting-adjusted multivariate analysis, IMRT was significantly associated with lower all-cause mortality (HR, 0.83; 95% CI, 0.72-0.95), cardiac mortality (HR, 0.18; 95% CI, 0.06-0.54), and other-cause mortality (HR, 0.54; 95% CI, 0.35-0.84). In this SEER-based analysis, the use of IMRT was found to be significantly associated with lower all-cause mortality, cardiac mortality, and other-cause mortality in patients with EC. Also, in a study of 676 patients with propensity score matching, compared with IMRT, 3D-CRT patients had a significantly greater risk of dying (72.6% vs 52.9%, inverse probability of treatment weighting, log-rank test, P<.0001) and of locoregional recurrence (P=.0038). No difference was seen in cancer-specific mortality (Gray’s test, P=.86) or distant metastasis (P=.0038) between the 2 groups. An increased cumulative incidence of cardiac death was seen in the 3D-CRT group (P=.049), but most deaths were undocumented (5-year estimate, 11.7% in 3D-CRT vs 5.4% in IMRT group, Gray’s test, P=.0029).

**Reference:**

134. According to the EBCTCGmeta-analysis, what is the strongest factor contributing to estimates of an absolute increase in cardiac risk from breast radiation?

A. Connective tissue disease  
B. Smoking status  
C. Hypertension  
D. Young age

**Key:** B

**Rationale:**
Smoking correlated with the greatest increase in risk for both cardiac morbidity and lung cancer.

**Reference:**
135. What is the appropriate surgical margin recommended for T1-2 N0 penile cancer?

A. 2 mm  
B. 3-10 mm  
C. 10-15 mm  
D. 15-20 mm

**Key:** B & C  
**NOTE:** This item was double-keyed for scoring purposes upon post-exam statistical item analysis.

**Rationale:**
Traditionally, a 2 cm surgical margin was recommended. However, a 5-10 mm margin is now recommended by the National Comprehensive Cancer Network, and a 3 mm margin is recommended by the European Association of Urology.

136. Which of the following has been shown to increase metastasis-free survival in patients with nonmetastatic (M0) castration resistant prostate cancer?

A. Abiraterone  
B. Docetaxel  
C. Apalatumide  
D. Casodex

**Key:** C

**Rationale:**  
A phase III randomized trial by Smith et al. demonstrated that in patients with nonmetastatic castration resistant prostate cancer, the use of Apalutamide when compared to placebo increased the median time to metastasis from 16.2 months to 40.5 months.

**Reference:**
137. What treatment is recommended for a 55-year-old female with a pT1N1mic grade 1, ER/PR + HER-2-breast cancer following breast-conserving surgery and sentinel node biopsy whose recurrence score is 11?
   A. Completion axillary LND followed by hypofractionated whole breast RT and adjuvant endocrine therapy
   B. Chemotherapy followed by hypofractionated whole breast and low axillary RT and adjuvant endocrine therapy
   C. APBI followed by adjuvant endocrine therapy
   D. Hypofractionated whole breast RT followed by adjuvant endocrine therapy

Key: D

Rationale:
The IBCSG 23-01 trial found that completion axillary lymph node dissection was unnecessary for women with a micro-metastasis identified on SLNB; most of these women received whole breast radiotherapy. Patients with a nodal micrometastasis were included in the TAILOR-X trial; therefore, there is no role for adjuvant chemotherapy with an Oncotype of 11. She has lymph node positive breast cancer thus APBI would not be recommended.

Reference:

138. Per QUANTEC, what maximum dose to the larynx with conventional fractionation gives a < 20% risk of permanent voice dysfunction?
   A. 30 Gy
   B. 45 Gy
   C. 55 Gy
   D. 66 Gy

Key: D

Rationale:
See QUANTEC summary table.

Reference:
139. For breast cancer, which lymph nodes are typically removed in an axillary dissection?

   A. Level I
   B. Level II
   C. Level I-II
   D. Level I-III

**Key:** C

**Rationale:**
Level I-II are routinely removed in an axillary dissection, but Level III (medial to pectoralis minor) is not

**Reference:**
RTOG Breast Atlas https://www.rtog.org/LinkClick.aspx?fileticket=vzJFhPaBipE%3d&tabid=236

140. What is preferred for a 3 cm vulvar cancer not involving the adjacent pelvic structures?

   A. Vulvectomy + nodal assessment
   B. EBRT + brachytherapy
   C. Template-based interstitial implant
   D. Chemotherapy followed by resection

**Key:** A

**Rationale:**
In vulvar cancer amenable to resection without need for exenteration, the initial management involves modified radical vulvectomy (i.e. resection with adequate margins) with the pathologic evaluation of inguinal lymph nodes.

**Reference:**
141. What is the OS at 5 years for the two groups studied in RTOG 1016, Cetuximab + RT vs Cisplatin + RT, respectively?

A. Cetuximab + RT 85%, Cisplatin + RT 78%
B. Cetuximab + RT 78%, Cisplatin + RT 85%
C. Cetuximab + RT 95%, Cisplatin + RT 90%
D. Cetuximab + RT 90%, Cisplatin + RT 95%

Key: B

Rationale:
Patients with human papillomavirus (HPV)-positive oropharyngeal squamous cell carcinoma have high survival when treated with radiotherapy plus cisplatin. Whether replacement of cisplatin with cetuximab— an antibody against the epidermal growth factor receptor—can preserve high survival and reduce treatment toxicity is unknown. In this trial, the aim was to investigate whether cetuximab would maintain a high proportion of patient survival and reduce acute and late toxicity. For patients with HPV-positive oropharyngeal carcinoma, radiotherapy plus cetuximab showed inferior overall survival and progression-free survival compared with radiotherapy plus cisplatin. Radiotherapy plus cisplatin is the standard of care for eligible patients with HPV-positive oropharyngeal carcinoma.

Reference:
142. What is the response rate to nivolumab for previously treated metastatic anal cancer?

A. 0%
B. 12%
C. 24%
D. 36%

Key: C

Rationale:
Squamous cell carcinoma of the anal canal (SCCA) is a rare malignancy associated with infection by human papillomavirus (HPV). Because intratumoral HPV oncoproteins upregulate immune checkpoint proteins such as PD-1 to evade immune-mediated cytotoxicity, anti-PD-1 antibody nivolumab for patients with metastatic SCCA was evaluated. single-arm, multicentre, phase 2 trial at ten academic centres in the USA. The primary endpoint was response according to Response Evaluation Criteria in Solid Tumors, version 1.1, in the intention-to-treat population. (ClinicalTrials.gov, number NCT02314169). 39 patients, of whom 37 were enrolled and received at least one dose of nivolumab. Among the 37 patients, nine (24% [95% CI 15-33]) had responses. There were two complete responses and seven partial responses. Grade 3 adverse events were anaemia (n=2), fatigue (n=1), rash (n=1), and hypothyroidism (n=1). No serious adverse events were reported. First completed phase 2 trial of immunotherapy for SCCA. Nivolumab was well tolerated and effective as a monotherapy for patients with metastatic SCCA. Immune checkpoint blockade appears to be a promising approach for patients with this orphan disease.

Reference:

143. Where is Broca’s area most likely to be located in a right-handed person?

A. Left frontal lobe
B. Left temporal lobe
C. Right frontal lobe
D. Right temporal lobe

Key: A

Rationale:
Broca’s area is typically in the dominant hemisphere, which is usually opposite the dominant hand. Broca’s area is located in dominant frontal lobe just superior to lateral sulcus while Wernicke’s area is located in the dominant temporal lobe at the posterior end of the lateral sulcus.

Reference:
144. In adults, where does the spinal cord typically end?

   A. L1  
   B. L3  
   C. L5  
   D. S1  

Key: A

Rationale: 
The spinal cord ends at around L1 in adults and around L3/4 in newborns. The thecal sac ends at S1/S2.

145. Which salivary tumor of the parotid gland is MOST likely to present with nodal metastases?

   A. Pleomorphic adenoma  
   B. Salivary ductal carcinoma  
   C. Adenoid cystic carcinoma  
   D. Low-grade mucoepidermoid carcinoma

Key: B

Rationale: 
Salivary ductal carcinomas are high-grade carcinomas with a propensity for lymph node spread; neck management is recommended. Adenoid cystic carcinoma is at lower risk of lymph node metastases. Pleomorphic adenomas are not malignancies but have a risk of malignant transformation over time. The risk of nodal spread is low for a low-grade mucoepidermoid carcinoma.

Reference:
146. Which molecular characteristic associated with diffuse glioma predicts an aggressive clinical course similar to that of glioblastoma?

A. IDH-mutant  
B. TERT promoter mutation  
C. 1p19q codeletion  
D. MGMT methylation

Key: B

Rationale:
Multiple studies have shown that there is a subset of IDH-wildtype gliomas that would be considered as WHO grade II or III based on histologic criteria but have an aggressive clinical course similar to that of IDH-wildtype glioblastoma, WHO grade IV. The molecular characteristics of these gliomas include EGFR amplification, combined whole chromosome 7 gain and whole chromosome 10 loss (+7/-10), and TERT promoter mutation (Brat et al, Acta Neuropathologica 2018).

Reference:

147. What is the approximate pCR rate after pre-operative RT in patients with soft tissue sarcoma?

A. 1%  
B. 10%  
C. 20%  
D. 30%

Key: B

Rationale:
In a single institution report, Schaefer et al evaluated the histologic appearance after pre-operative radiation in patients with soft tissue sarcoma using the EORTC-STBSG Response Score criteria for assessment. The observed pathologic complete response rate was 9% in this cohort of 100 patients with STS treated with pre-op RT. Unlike in bone sarcoma where response (>95% necrosis following neoadjuvant chemotherapy) is predictive of favorable RFS and OS, histologic treatment response score based on percent viable cells was not prognostic for outcome after pre-op RT for soft tissue sarcoma.

Reference:
148. Radiation therapy can be used as a salvage option for rejection of renal transplant allografts refractory to medical immunosuppression. Which of the following is a reasonable radiation therapy dose delivered to the local renal graft?

A. 3 Gy in 1 fx  
B. 6 Gy in 1 fx  
C. 3 Gy in 3 fx  
D. 6 Gy in 3 fx

**Key:** D

**Rationale:**
Radiation therapy to a dose of 6-8 Gy in 2 Gy fractions is well tolerated and is a viable salvage treatment option for patients having undergone rejection of renal transplant that has been refractory to medical immunosuppression.

**Reference:**

149. Which form of hysterectomy is preferred for low grade endometrial carcinoma, clinically confined to the uterus?

A. Laparoscopic total hysterectomy  
B. Radical hysterectomy  
C. Vaginal hysterectomy  
D. Supracervical hysterectomy

**Key:** A

**Rationale:**
Surgery is the recommended initial intervention for endometrial cancer. Open and laparoscopic (including the robotic-assisted method) approaches are safe and effective. The role of vaginal hysterectomy is much less clear in neoplastic disease. Various forms of radical hysterectomy are used for cervical cancer.

**Reference:**
In the LAP07 study of locally advanced pancreatic cancer demonstrated that:

A. chemoradiation improved OS.
B. chemoradiation improved local progression.
C. the addition of erlotinib to gemcitabine improved OS.
D. the addition of erlotinib to gemcitabine improved local progression.

Key: B

Rationale:
The trial consisted of two randomizations. First, it tested the addition of erlotinib to gemcitabine systemic therapy. This did not increase overall survival. After 4 months of systemic therapy, it randomized patients to continuing chemotherapy or switching to chemoradiation. This was not associated with an overall survival benefit, but was associated with decreased local progression. Nausea was the only grade 3-4 toxicity that was increased with chemoradiation.

Reference:

Which action improves the dose homogeneity when treating with same-energy, parallel-opposed photon treatment fields?

A. Using uneven beam weighting
B. Increasing the treatment volume separation
C. Decreasing the treatment field size
D. Increasing the photon beam energy

Key: D

Rationale:
Higher beam energies penetrate the body easier, thus leading to less attenuation and hence a more flat, uniform dose across the patient. An uneven weighting will increase dose at the entrance point of the field weighted heavier. A larger separation decreases uniformity. Decreasing the field size will not increase homogeneity and may potentially decrease it.

Reference:
152. Why are cancer stem cells important targets of anti-cancer treatment?

A. Support the development of secondary cancers
B. Responsible for chemoradiation toxicities
C. Able to repair normal tissue damage
D. Resistance to radiation therapy

Key: D

Rationale:
Cancer stem cells are pluripotent cells with high replicative potential, resistance to therapy, and ability to repopulate an entire tumor through differentiation. They are thought to be responsible for metastases and may be increased in sites of metastatic disease.

Reference:

153. Which phase of the cell cycle is most sensitive to hyperthermia induced cell killing?

A. G1
B. S
C. G2
D. G0

Key: B

Rationale:
The two principal rationales for applying hyperthermia in cancer therapy are that: (a) the S phase, which is relatively radiation resistant, are most sensitive phase to hyperthermia, and can be selectively radiosensitized by combining hyperthermia with x-irradiation; the cycling tumor cells in S phase which would normally survive an x-ray dose could thus be killed by subjecting these cells to hyperthermia. For heat shock during S phase, however, the damage in the chromatin is reflected as chromatid aberrations in all the chromosomes. These aberrations apparently induce cell lethality, just as do x-ray-induced chromosomal aberrations.

Reference:
154. For an open, flattening filter free beam, at what location within the photon beam is the dose rate the highest?

A. Central beam axis  
B. Off axis  
C. Penumbra region  
D. Bragg peak

Key: A

Rationale:  
Photons that are generated in the linac target are primarily forward directed at MV energies. This results in a photon fluence that is a maximum on the beam central axis then decreases laterally. In flattening filter free beams, there is no flattening filter to preferentially attenuate the central axis photon fluence. The resulting photon fluence, and therefore dose rate, is highest on the beam central axis.

Reference:  

155. When implementing a TBI program in an existing vault, how does the use factor change for the wall facing the beam with respect to the other walls in the vault?

A. Increases  
B. Decreases  
C. No change  
D. Decreases for higher energies

Key: A

Rationale:  
During TBI treatments, the gantry stays in a single position while the patient is repositioned in order to deliver fields from both sides. Thus, the beam is angled at a single wall during the entire treatment. The use factor of that wall (or proportion the beam faces that wall) will be larger compared to other walls in the room.

Reference:  
156. What oncological outcomes did the ACOSOG Z4032 trial by Fernando et al., that randomized medically high-risk early stage lung cancer patients to receive a sublobar resection +/- $^{125}$I mesh brachytherapy demonstrate?

A. Decreased local recurrence
B. Increased OS
C. Increased cancer-specific survival
D. No difference in local recurrence

Key: D

Rationale:
There was no difference in time to local recurrence (HR, 1.01; 95% CI, 0.51 to 1.98; log-rank P = 0.98) or in the types of local recurrence. Local progression occurred in only 17 (7.7%) of 222 patients. In patients with potentially compromised margins (margin < 1 cm, margin-to-tumor ratio < 1, positive staple line cytology, wedge resection, nodule size > 2.0 cm), the addition of brachytherapy did not reduce local recurrence, although trends favored the brachytherapy arm. This was most marked in 14 patients with positive staple line cytology (HR, 0.22; P = 0.24). Three-year overall survival rates were similar for patients in the sublobar resection (71%) and sublobar resection plus brachytherapy (71%) arms (P = .97).

Reference:

157. Radiation carcinogenesis risk estimates have been largely derived from the life span study (LLS) of Japanese atomic bomb survivors. How might the newer Million Person Study (MPS) prove more useful for determining carcinogenic risk for American radiation workers?

A. MPS examines more cancer sites than the LSS
B. MPS has longer follow up times than the LSS
C. MPS has a better control group for comparisons
D. MPS subjects were exposed chronically

Key: D

Rationale:
The LSS has long been the gold standard for radiation induced carcinogenic risk estimation as it has a large sample size, a more than adequate control group for comparisons and has a long follow up period. The inherent weakness of the study for setting protections standards for radiation workers is that it measures the effects of a single acute dose. In contrast, the subjects of the MPS were exposed to various doses chronically which would simulate cancer risks in radiation worker population better.

Reference:
158. How do the gonadal effects of irradiation compare between males and females?

A. Permanent sterility after single 2 Gy dose in males
B. Permanent sterility after single 2 Gy dose in pre-puberty females
C. No effect of fractionated exposure in males or females
D. Age dependency for sterility in females

Key: D

Rationale:
There is an age dependency for sterility in females. Permanent sterility in women is seen after 12 Gy pre-puberty and 2 Gy post-puberty. There is no latent period for damage in females, unlike males. In males a single dose of 6 Gy is needed for permanent sterility; total dose of 2-3 Gy if fractionated. Irradiation produces hormone changes in females and not males.

Reference:

159. What is a factor that should be considered in a CTV to PTV expansion?

A. Microscopic invasion into surrounding tissue
B. Dose fractionation
C. Serial or parallel nature of the CTV
D. Patient immobilization

Key: D

Rationale:
CTV to PTV expansion is determined by physical factors such as immobilization, image guidance, etc. Choice B and C are irrelevant and choice A is only relevant for GTV to CTV expansion.

Reference:

160. Which patients with Hodgkin lymphoma may benefit the MOST from proton radiotherapy?

A. Male with upper mediastinal involvement only
B. Female with lower mediastinal involvement only
C. Female with right cervical involvement only
D. Male with right axillary involvement only

Key: B

Rationale:
Proton therapy is most helpful among patients with lower mediastinal involvement, due to dose reduction to the heart, and among females with axillary involvement.

Reference:
For a pediatric ALL patient with a CNS3 relapse > 18 months following first CR, what is the appropriate RT after high dose methotrexate-based systemic therapy and intrathecal therapy?

A. 18 Gy cranial and 15 Gy spinal RT
B. 18 Gy cranial RT
C. 24 Gy cranial and 15 Gy spinal RT
D. 24 Gy cranial RT

**Key:** B

**Rationale:**
POG9412 built on and successfully further de-escalated the use of cranial and spinal radiotherapy at the time of relapse in ALL with CNS involvement relative to POG 9061 (PMID: 16809737). As a result, only patients with relapses <18 months from the time of the first complete remission will receive 24 Gy cranial radiotherapy and 15 Gy spinal radiotherapy in the setting of an isolated relapse. While criteria for cranial radiotherapy in POG9412 was specified as CNS2c or greater, more recent protocols specify that patients receive CNS directed radiotherapy who have CNS3 disease. For example, patients with CNS3 disease as a component of a systemic relapse should have CNS directed radiotherapy in combination with TBI when transplant is part of the planned salvage regimen (i.e. AALL1331). While current CNS classification criteria include blasts, WBC and RBC, it appears that CNS blasts are the dominant independent predictor of impaired EFS and OS (PMID: 28535084).

**Reference:**
AALL1331 - https://clinicaltrials.gov/ct2/show/NCT02101853
162. Neurons are likely to die by which mechanisms after radiation?

A. Apoptosis  
B. Mitotic catastrophe  
C. Senescence  
D. Necrosis  

Key: C  
Rationale:  
Neurons are usually regarded as post-mitotic cells and do not divide; eliminating mitotic catastrophe as a mode of cell death. Likewise, neurons can exhibit apoptosis and necrosis during nervous system development and neurogenesis but not post mitotically after irradiation. Post mitotic neurons undergo senescence after exposure to IR.  
Reference:  

163. What agent interacts with Cytotoxic T-lymphocyte antigen 4 (CTLA-4)?

A. Atezolizumab  
B. Ipilimumab  
C. Avelumab  
D. Durvalamab  

Key: B  
Rationale:  
Avelumab, atezolizumab, and Durvalamab all inhibit program death ligand 1 (PD-L1). Ipilimumab is a cytotoxic T-lymphocyte antigen 4 (CTLA-4) inhibitor.  
Reference:  
164. What assay can be used to measure radiation-induced cellular senescence?

   A. TUNEL assay
   B. Propidium Iodine absorption
   C. X-gal cleavage
   D. Annexin V assay

   **Key:** C

   **Rationale:**
   The X-gal (5-bromo-4-chloro-3-indolyl-β-D-galactopyranoside) assay is based on senescence-associated β-galactosidase activity. This enzyme cleaves X-gal into an insoluble blue moiety; the presence of which is taken to indicate senescence. This assay is not without caveats as factors other than senescence can produce this activity.

   **Reference:**
   Dimri, GP et al., A biomarker that identifies senescent cells in culture and aging cells in vivo.

165. Expression of what cell surface marker acts as a “brake” on the immune system and prevents immune cell tumor recognition?

   A. CD20
   B. PD-L1
   C. HER2/neu
   D. EGFR

   **Key:** B

   **Rationale:**
   EGFR is a growth factor receptor. PD-L1 is a transmembrane protein that plays a major role in suppressing the immune system. CD-20 is a B-cell marker. HER2/neu is a growth factor receptor.

   **Reference:**
166. What is a DISADVANTAGE of using high energy (e.g. 15-20 MV) photon beams for peripheral lung lesions?

   A. Decreased beam penumbra
   B. Decreased beam penetration (lower PDD)
   C. Decreased peripheral dose to the lesion
   D. Decreased entrance dose to the skin

   **Key:** C

   **Rationale:**
The lower density of the lung causes an increasing number of electrons traveling out of the beam, which results in a reduction of dose to the periphery of the target.

   **Reference:**

167. What were the treatment arms in a recent randomized study (IMpower133) that established a new standard of care for systemic therapy in extensive-stage SCLC?

   A. Carboplatin/etoposide vs pembrolizumab
   B. Carboplatin/etoposide vs carboplatin/pembrolizumab
   C. Carboplatin/etoposide vs carboplatin/atezolizumab
   D. Carboplatin/etoposide +/- atezolizumab

   **Key:** D

   **Rationale:**
The IMpower133 trial evaluated the efficacy and safety of adding atezolizumab or placebo to first-line treatment with carboplatin and etoposide in patients with extensive-stage small-cell lung cancer. Atezolizumab improved median overall survival (mOS) from 10.3 months to 12.3 months (P=0.007), and median progression-free survival (mPFS) from 4.3 months to 5.2 months (P=0.02), with the effects on survival consistent across tumor mutational burden subgroups. Confirmed objective response was similar between the atezolizumab group (60.2%) and the placebo group (64.4%). Carboplatin/etoposide plus atezolizumab is now the NCCN category 1 preferred option in this scenario. Atezolizumab is now being evaluated as part of primary chemoradiation in the phase 3 randomized trial – NRG LU005.

   **Reference:**
168. Which is a radioimmunotherapy agent used to treat NHL?

   A. Brentuximab Vedotin
   B. Bendamustine
   C. Ibritumomab
   D. Nivolumab

Key: C

Rationale:
Ibritumomab is used with yttrium 90 labeling as immunotherapy.

169. For a low energy, poly-energetic X-ray beam, the second half-value layer (HVL) as compared to the first HVL is:

   A. smaller.
   B. the same.
   C. larger.
   D. larger only for small field sized.

Key: C

Rationale:
Because of beam hardening, the second HVL will be larger than the first HVL as the x-ray energy will increase.

Reference:
170. What is MOST appropriate regarding RT for multiple myeloma of long bones requiring internal fixation and hardware placement?

A. RT should be avoided to minimize risk for hardware failure
B. RT should be given to only a portion of the hardware to reduce risk for recurrence
C. RT should be given to the entire hardware to reduce risk for recurrence
D. RT should be given immediately after surgery to reduce risk for infection associated with hardware placement

Key: C

Rationale:
Elhammali et al identified 33 patients with 40 different sites treated. The most common dose and radiation fractionation was 20-25 Gy in 8 to 12 fractions. In cases where full hardware coverage was not done, they noted an increased risk for recurrence (HR of 6.44, p = 0.04) and none of the recurrences resulted in hardware failure. Radiotherapy should be given once a patient has healed after surgery in order to minimize risk for infection. Earlier radiotherapy, immediately postoperatively, may actually increase risk for infection since full healing has not taken place after surgery. The standard is to wait several weeks after surgery before starting radiotherapy.

Reference:

171. What is the most appropriate radiation treatment for a 10-year-old patient with a 3 cm upper extremity embryonal rhabdomyosarcoma without nodal or distant metastases that has a partial response to induction chemotherapy and is planned for definitive chemoradiation?

A. 50.4 Gy to the primary site and no nodal radiation
B. 59.4 Gy to the primary site and no nodal radiation
C. 45 Gy to primary site and 41.4 Gy to the draining lymph nodes
D. 50.4 Gy to the primary site and 41.4 Gy to the draining lymph nodes

Key: A

Reference:

Rationale:
Draining lymph nodes are only treated when they have been established to be involved. Some single institution studies suggest prophylactic nodal irradiation could be considered in parameningeal sites. The established dose for gross residual disease is 50.4 Gy in 28 fractions when given with concurrent chemotherapy. COG ARST1431 is examining the role of dose escalation to 59.4 Gy in patients with primary disease sites >5 cm.
172. What is the equivalent square field size of a rectangular 10 x 15 cm^2 field?

A. 11 x 11 cm^2  
B. 12 x 12 cm^2  
C. 13 x 13 cm^2  
D. 14 x 14 cm^2

Key: B

Rationale:
Using the equivalent square formula \( \frac{A}{P} = \frac{l \times w}{2 \times (l + w)} \), a 10 x 15 cm^2 rectangular field is equivalent to a 12 x 12 cm^2 square field.

Reference:

173. What is the primary radiobiological rationale of accelerated hyper-fractionation?

A. Reduce the extent of intra-tumoral hypoxia  
B. Reduce the level of acute normal tissue toxicity  
C. Diminish the repopulation of tumor cells  
D. Decrease late effects while improving tumor control

Key: D

Rationale:
The primary goal of hyperfractionation is to decrease the incidence of late effects by maintaining or improving tumor control and thus improving the therapeutic ratio. This is accomplished if the late responding normal tissue has a lower alpha/beta ratio than the tumor.

Reference:
A population of cells is irradiated with 1 Gy of γ-rays. What would the surviving fraction be using the multi-target single hit (MTSH) model if $D_0 = 1$ and $n = 1$; assuming 100% plating efficiency?

A. 0.09  
B. 0.19  
C. 0.37  
D. 0.63

**Key:** C

**Rationale:**
While the Multi-Target Single Hit model is no longer widely used, the parameters, particularly $D_0$, are often used to describe radiation cell survival curves, particularly when comparing sensitivities of different cell lines or changes in response following alterations in treatment. This model was derived to explain the shape of mammalian cell survival curves before the current knowledge cell and molecular biology of radiation effects were known. It was assumed that cells contained a limited number of critical targets. If any of these targets were hit the cell would be killed. The probability of a target being hit was proportional to dose ($D$); $P_{hit} = kD$.

For a cell to survive, 0 targets are hit. From Poisson statistics, the probability of 0 hits would be; $P_0 = e^{-\lambda}$; where $\lambda$ = the mean number of hits per cell at a given dose. Survival then is; $S = e^{kD}$. If we define $D_0$ as $1/k$ then $S = e^{-D/D_0}$. To inactivate or “kill” one target; $K = 1 - (e^{D/D_0})$. To inactivate a cell with $n$ targets; $K = 1 - (e^{D/D_0})^n$. This leaves us with:

$$S = 1 - (1 - e^{-D/D_0})^n$$

Substituting in values from our question:

$$S = 1 - (1 - e^{-1/1})^1$$

$S = 0.37$.

**Reference:**
175. Which radiation source is likely to cause the MOST clustered chromosome breaks?

A. Photons  
B. Protons  
C. Electrons  
D. Carbon ions

Key: D

Rationale:  
Carbon ion radiation is high LET radiation and leads to clustered damage in DNA. The high localization of DNA damages from high LET irradiations, are more likely to cause clustered chromosome abnormalities. The increased toxicity of high LET radiation and the extensive genomic rearrangements associated with chromothripsis.

Reference:  

176. What is the AJCC 8th edition stage group for a 5.1 cm thymic malignancy invading the pericardium with 2 peri-thymic lymph nodes and no separate pleural, pericardial or distant metastases?

A. II  
B. IIIA  
C. IIIB  
D. IVA

Key: D

Rationale:  
The staging would be T2N1M0, stage group IVA. Anterior/perithymic lymph nodes (N1) or separate pleural or pericardial nodules (M1a) would be stage IVA. Deep intrathoracic or cervical lymph nodes (N2) or pulmonary intraparenchymal nodule / distant organ metastasis (M1b) would be stage IVB.

Reference:  
177. What was the impact of early palliative care in addition to standard oncological care in patients with metastatic NSCLC, based on the randomized study by Temel et al (NEJM 2010)?

A. QoL benefits but shorter OS  
B. QoL benefits and longer OS  
C. No impact on QoL and shorter OS  
D. No impact on QoL but longer OS  

Key: B  

Rationale:  
Among patients with metastatic non-small-cell lung cancer, early palliative care led to significant improvements in both quality of life (FACT-L score) and lower depressive symptoms (Hospital Anxiety and Depression Scale). As compared with patients receiving standard care, patients receiving early palliative care also had longer survival (11.6 months vs 8.9 months, p=0.02) even though aggressive end-of-life care was offered to fewer patients in the early palliative care group than in the standard care group received (33% vs. 54%, P=0.05).

Reference:  

178. What is FDA approved to minimize acute radiation syndrome in the event of a radiation emergency?

A. Amifostine  
B. Sargramostim  
C. Cisplatin  
D. Gefitinib  

Key: B  

Rationale:  
Cisplatin is a chemotherapy agent that induces DNA cross linkages; amifostine is used to reduce the side effects of chemotherapy and radiation; gefitinib is a tyrosine kinase inhibitor that targets the epidermal growth factor receptor; none of these compound is approved for use in a radiation emergency. Sargramostim is indicated to increase survival in patients exposed to myelosuppressive doses of radiation.

Reference:  
https://www.fda.gov/drugs/bioterrorism-and-drug-preparedness/radiation-emergencies
179. What were the outcomes for the radiation patients who had PET CR in the recently published LYSA-Group Phase 2 randomized trial of 4-6 cycles of RCHOP +/- RT for non-bulky (<7cm) limited stage DLBCL patients?

A. EFS was worse, OS was better
B. EFS was better, OS was worse
C. EFS was same, OS was same
D. EFS was same, OS was better

Key: C

Rationale:
The event free and overall survival were the same at 5 year with the addition of 40 Gy RT if patients had PET based CR after 4 cycles of R-CHOP. The 5 yr EFS was 89% in RCHOP alone arm vs 92% in the RCHOP+RT arm (not-significant). The 5 yr OS was 92% in RTCHOP alone arm and 96% in RCHOP+RT arm (Non-significant).

Reference:

180. For low LET radiations delivered at high dose rate, what does the $\beta D^2$ term of the linear-quadratic ($\alpha/\beta$) model describe?

A. Lethal DNA DSB from two proximate single strand breaks from the same particle track
B. Lethal DNA DSB from the misrepair of two proximate base damage lesions from same particle track
C. Lethal lesions from the interaction of two proximate sublesions produced by independent particle tracks
D. Lethal DNA lesion from a single particle track

Key: C

Rationale:
The linear quadratic model of cell survival derives from Kellerer and Rossi’s Theory of Dual Radiation Action. This model postulates a linear-quadratic dose response resulting from the interaction of spatially and temporally proximate pairs of “sublesions” to form lethal lesions that kill the cell. In some cases, both sublesions are formed by the same charged particle track. This forms the linear ($\alpha D$) portion of the curve. The quadratic ($\beta D^2$) portion results when the interacting sublesions are produced by separate and independent particle tracks.

Reference:
181. For an electron field, which relative isodose line is located at the field edge projected on the patient surface?

A. 30%
B. 50%
C. 80%
D. 90%

**Key:** B

**Rationale:**
The relative isodose line at the edge of the field is 50% at the patient surface and follows the projected field edge to approximately the depth of maximum dose. Higher isodose lines are located more centrally in the field and become increasingly central as depth increases due to increased scattering of the beam. As such electron treatments with typical prescriptions (i.e. dose to the 80% or 90% isodose level) require larger fields as compared to photons to ensure target coverage.

**Reference:**

182. From NCRP-116, which organ has the highest tissue weighting factor?

A. Liver
B. Lung
C. Thyroid
D. Esophagus

**Key:** B

**Rationale:**
Radiation sensitivity for organs may be quantified by using the tissue weighting factor ($W_T$) as outlined in NCRP-116. From the list, lung has a $W_T$ of 0.12 while all of the other are 0.05.

**Reference:**
183. Which molecular subgroup of medulloblastoma has the BEST prognosis?

A. WNT
B. SHH
C. Group 3
D. Group 4

Key: A

Rationale:
WNT pathway tumors are the least common subgroup of medulloblastoma, but have the best prognosis, with at least 95% survival at 5 years.

Reference:

184. Rapidly proliferating brain tumor cells are likely to die by which mechanisms after radiation?

A. Apoptosis
B. Mitotic catastrophe
C. Senescence
D. Necrosis

Key: B

Rationale:
Rapidly growing tumor cells often die by mitotic catastrophe after IR due to loss of checkpoint controls that detect DNA damage and prevent induction of mitosis. When cells transit mitosis with unresolved or unrepaired DNA double strand breaks chromosome aberrations can result leading to mitotic catastrophe.

Reference:
185. What is a limitation of the AAPM TG-43 brachytherapy dose calculation methodology?

A. It uses apparent activity for the source strength
B. It assumes that sources are point sources
C. It does not account for inhomogeneities
D. It does not account for anisotropy

Key: C

Rationale:
The TG43 dosimetry system uses air kerma strength, rather than apparent activity, to describe the strength of a radioactive source. Although under some circumstances the source can be approximated as a point source, this is not required in the TG43 system. The TG43 system takes account of anisotropy but does not account for inhomogeneities.

Reference:

186. What prominent radiobiological characteristic would be exhibited for a survival curve with an α/β ratio of 3?

A. High capacity for sublethal damage repair
B. Incident radiation was very high LET
C. Absence of repair of lethal lesions
D. Very low dose rate would increase cell kill

Key: A

Rationale:
A low α/β indicates a high capacity for sublethal damage repair in with cell death. Cell death with very high LET is generally an exponential (vs quadratic) function, represented by a high α/β ratio. Increasing dose rate could increase cell kill.

Reference:
187. What is considered a biomarker of ionizing radiation-induced DNA double strand breaks?

A. Annexin V
B. γ-H2Ax
C. Nuclear factor-κB
D. Lactate dehydrogenase

Key: B

Rationale:
Cells respond to the formation of DNA double strand breaks by phosphorylating histone H2AX. The phosphorylated form of this histone, γ-H2AX, is one of the first steps in recruiting DNA repair proteins. To assess the formation of DNA double strand breaks, cells and tissues are commonly stained for the presence of γ-H2AX. Its formation and resolution with time after radiation exposure can be used as a surrogate marker for the initial number and residual number of DNA breaks.

Reference:

188. Which of the following photo-electron interactions result in zero energy being absorbed locally in the medium?

A. Coherent scattering
B. Photoelectric effect
C. Compton effect
D. Pair production

Key: A

Reference:
189. For a cervical brachytherapy implant using the Manchester system, which point should receive the highest dose?

A. Point A  
B. Point B  
C. Bladder point  
D. Rectum point

Key: A

Rationale:
Point A is the prescription point and should receive the highest dose—i.e. the prescription dose. Point B should be 30-40% of point A. Bladder and rectum points should receive < 80% of point A.

Reference:

190. A parallel-plate chamber is MOST appropriate when making dose measurements of which radiation beam?

A. 6 MV photon  
B. 15 MV photon  
C. 4 MeV electron  
D. 18 MeV electron

Key: C

Rationale:
The small electrode spacing of a parallel-plate chamber minimizes cavity perturbations in the radiation field. For low energy electron beams, cylindrical chambers may produce significant perturbations and because of this, a parallel-plate chamber would be most optimal for 4 MeV.

Reference:
191. Charged particle interactions with MATTER are predominately mediated by which effect?

A. Photoelectric effect  
B. Compton effect  
C. Pair production  
D. Direct ionization

**Key:** D

**Rationale:**
Charged particles interact with matter principally through ionization and excitation. The photoelectric effect, Compton effect, and pair production are photon interactions and not charged particle interactions.

**Reference:**

192. What is the AJCC 8th edition TNM group for a 68-year-old smoker has a PET/CT which shows a 3.2 cm right middle lobe FDG avid mass and right hilar (level 10R), subcarinal (level 7) and subaortic (level 5) lymph nodes, with subcarinal lymph node biopsy confirming adenocarcinoma?

A. T2aN2M0  
B. T2bN2M0  
C. T2aN3M0  
D. T2bN3M0

**Key:** C

**Rationale:**
T2a tumors are greater than 3 cm but less than or equal to 4 cm. Level 5 and Level 6 lymph nodes are considered contralateral mediastinal lymph nodes for right-sided primary lung tumors. Contralateral mediastinal or hilar lymph nodes or supraclavicular lymph nodes are categorized as N3.

**Reference:**
193. How many times greater is the mass of a proton compared to an electron?

A. 20
B. 200
C. 2,000
D. 20,000

**Key:** C

**Rationale:**
Protons are positively charged particles and relatively massive; approximately 2000 times the mass of electrons.

**Reference:**

194. Which is TRUE regarding leukemia cutis?

A. It rarely involves the lower extremities
B. TSET should be considered for limited extent of disease
C. 24 Gy in 12 fractions can provide durable symptomatic relief
D. It characteristically develops prior to the onset of systemic leukemia

**Key:** C

**Rationale:**
Leukemia cutis rarely develops before the onset of systemic leukemia and more commonly develops concurrently. The most common location is the lower extremities. Total skin electron beam therapy is typically not appropriate if bone marrow is involved unless disease is diffuse and symptomatic. 24 Gy in 12 fractions is recommended by ILROG guidelines.

**Reference:**
195. Which of the following represents a QA methodology, using a ratio of ion chamber of measurements, for assessing the constancy of the beam quality (energy) of a photon beam?

A. Measurement on the central axis at two different positions in air  
B. Measurement on the central axis at two different positions in water  
C. Measurement at the same source-to-detector distance on-axis and off-axis in air  
D. Measurement at the same source-to-detector distance on-axis and off-axis in water

Key: B

Rationale:
Taking the ratio of two points on the central axis of a depth-dose curve in water relates to beam energy, whether the ratio at 10 cm and depth of maximum dose (AAPM standard) or the ratio at 20 cm and 10 cm (IAEA standard). Off-axis ratios do not provide depth-dose information, and the measurement should be performed in water as the dosimetric qualities of interest such as attenuation and stopping power are medium-dependent.

Reference:
Almond et al., AAPM’s TG-51 protocol for clinical reference dosimetry of high-energy photon and electron beams, AAPM, Med Phys 26(9), 1999, pg. 1854-1856.

196. Regarding the use of durvalumab after chemoRT in the management of stage III NSCLC:

A. PD-L1 staining ≥50% is needed.
B. improved OS and increased grade 3 pneumonitis is seen.
C. improved OS and PFS without increase in grade 3 pneumonitis is seen.
D. shorter time to death or distant metastases is seen.

Key: C

Rationale:
Choice A is incorrect since there is no PDL1 selection in the USA, but in the European Union a PDL1 (Tumor Proportion Score [TPS] > 1% is needed for durvalumab to be approved for use after chemoradiation. Choice B is incorrect because durvalumab improve OS and PFS without significantly contributing to grade 3 pneumonitis. There was only slightly higher risk of grade 2 pneumonitis with durvalumab. The median time to death or distant metastasis was 28.3 months in the durvalumab group and 16.2 months in the placebo group (stratified hazard ratio, 0.53; 95% CI, 0.41 to 0.68).

Reference:
197. A 3-year-old patient presents with a 6 cm embryonal rhabdomyosarcoma of the low neck with draining lymph node involvement and without metastatic disease. What is the disease stage?

A. 1
B. 2
C. 3
D. 4

**Key:** A

**Reference:**

**Rationale:**
Staging of rhabdomyosarcoma is very dependent on site of disease. Patients with non-parameningeal head and neck rhabdomyosarcoma have stage 1 disease regardless of the size of the primary tumor and whether there are lymph nodes involved. Other favorable sites that are also considered stage 1 include orbit, Non-bladder/prostate GU, and biliary tract/liver.

198. The inhibition of what protein blocks epithelial–mesenchymal transition (EMT) to reduce pulmonary fibrosis?

A. RIPK3
B. SMAD3
C. FADD
D. Ki67

**Key:** B

**Rationale:**
Pulmonary fibrosis is characterized by the production of TGFβ; active TGFβ binds to pairs of two distinct transmembrane receptors TGFβR1 and TGFβR2. Smad (receptor-regulated Smads) proteins are involved in downstream signaling after TGFβ (SMAD1, 2, 3, 5 and 8). There are two inhibitory Smads (SMAD6 and 7) that antagonize TGFβ signaling. TGFβ promotes terminal differentiation along a lineage from proliferation-capable progenitor fibroblasts to postmitotic functional fibrocytes. Epithelial–mesenchymal transition (EMT) recognized in fibrogenesis. Loss of SMAD3 blocks EMT and reduces fibrogenesis.

**Reference:**
199. Which of the following presents the greatest challenge to commissioning a treatment planning system for IMRT?

   A. Application of smaller margins  
   B. Delivery at higher dose rates  
   C. Stricter output calibration standards  
   D. Superposition of small fields

   Key: D

   Rationale: Accurate modelling of small-field dose distributions is the greatest challenge for calculating intensity-modulated fields in a treatment planning system. Because IMRT requires the superposition of many small fields, inaccuracies in the model can accumulate to create a treatment plan dose calculation that is not representative of actual delivery. The dose rate is not a factor if the underlying model is accurate. While smaller margins may be applied in IMRT, these are primarily determined by the imaging and immobilization techniques supporting the treatment plan. Output calibration is performed in a standardized geometry and is not dependent on delivery technique.


200. In the RTOG 0617 trial testing 60 Gy vs 74 Gy in locally advanced NSCLC, which OAR dosimetric parameter was an independent prognostic factor for OS?

   A. V20 of the lung  
   B. Mean lung dose  
   C. V30 of the heart  
   D. Mean right ventricle dose

   Key: C

   Rationale: In the RTOG 0617 trial, the only dosimetry parameters that were prognostic were the V5 and V30 of the heart (Bradley et al., Lancet Oncol 2015) (choice C). The other parameters were not prognostic for survival.

201. In the RTOG 0813 Phase I/II clinical trial by Bezjak et al. evaluating the MTD of a 5-fraction regimen of SBRT for centrally located early stage NSCLC what were the constraints utilized for tracheal and ipsilateral bronchus (non-adjacent wall)?

A. Maximum point dose < 115% prescribed dose  
B. Maximum point dose < 85% prescribed dose  
C. V18 Gy < 4 cc  
D. V50 Gy < 0.5 cc

Key: C

Rationale:
The nonadjacent wall of the tracheal and ipsilateral bronchus was allowed a maximum point dose of 105% of the prescribed dose with V18 Gy restricted to less than 4 cc. Similar volumetric constraints were also specified for nonadjacent wall of esophagus and great vessels.

Reference:

202. What is the principle consequence of embryonic irradiation < 16 weeks as defined from atomic-bomb survivors in Japan?

A. Microcephaly  
B. Congenital malformations  
C. Increased carcinogenesis  
D. Tall stature

Key: A

Rationale:
The effects of radiation to the embryo and fetus depend upon the stage of gestation, the dose, and the dose rate. Congenital malformations are seen with radiation in the early (2-6 weeks) phases of development. Severe mental retardation is nearly 4 times more common if the radiation is received between 8 and 15 weeks than if it is received later. Children exposed in utero are shorter, lighter, and have a smaller head diameter than those not exposed to radiation.

Reference:
Radiobiology for the radiologist – Hall and Giaccia Chapter 12 p172-180 6th Edition  
Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2, 2006.  
203. With a patient in the head-first supine position, an anterior-posterior (AP) beam is delivered on a linear accelerator using International Electrotechnical Commission (IEC) standards. What is the gantry angle?

A. 0°
B. 90°
C. 180°
D. 270°

**Key:** A

**Rationale:**
IEC report 61217 defines gantry 0° at the 12 o’clock position when facing the gantry. Therefore, a patient irradiated in the supine position will have an anterior-posterior beam directed from the gantry IEC 0° position.

**Reference:**

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204. How many millimeters of lead are required to reduce the exposure rate of a source (Pb TVL = 4 mm) from 200 mrem/hr to 2 mrem/hr?

A. 4 mm
B. 8 mm
C. 12 mm
D. 16 mm

**Key:** B

**Rationale:**
200 mrem/hr requires two tenth-value layers to reduce the dose rate to 2 mrem/hr. The first tenth value layer reduces 200 mrem/hr to 20 mrem/hr, while the second reduces 20 mrem/hr to 2 mrem/hr. Two tenth value layers equates to 8 mm of lead since one-tenth value layer is 4 mm.

**Reference:**
205. What should treatment of a 3-year-old patient with metastatic high-risk neuroblastoma include?

A. Resection of the primary mass at the time of diagnosis
B. Radiation of the pre-chemotherapy extent of tumor
C. Induction chemotherapy followed by immunotherapy
D. Two cycles of high dose chemotherapy and autologous SCT

Key: D

Rationale:
The correct sequence is tumor biopsy, induction chemotherapy, resection, two cycles of high dose chemotherapy with autologous stem cell transplant, consolidative radiation to the extent of tumor at time of resection, and then immunotherapy. Neuroblastoma typically responds to induction chemotherapy so upfront resection commits the radiation oncologist to treating a larger volume than if the tumor is resected after chemotherapy. COG ANBL0532 established that in most high-risk patients two cycles of autologous stem cell transplants is superior to one.

Reference:
Provide at least one citation supporting the correct answer, after the item has been written (i.e. do not find a reference source and then write the item): JAMA. 2019 Aug 27; 322(8):746-755. doi: 10.1001/jama.2019.11642; J Clin Oncol. 2015 Sep 20; 33(27):3008-17.

206. Which electron energy exhibits the lowest surface dose?

A. 6 MeV
B. 9 MeV
C. 12 MeV
D. 15 MeV

Key: A

Rationale:
Unlike photon beams, surface dose increases with increasing electron beam energy.

Reference:
207. What is a major regulator of cell death after exposure to ionizing radiation?

A. Activated protein C  
B. CD45  
C. Myosin  
D. p53  

Key: D  

Rationale:  
In a normal cell, p53 is inactivated by its negative regulator, Mdm2. Upon DNA damage such as from ionizing radiation, p53 dissociates from Mdm2 and becomes active. Once activated, p53 determines whether the cell undergoes cell cycle arrest to repair the damage, or whether it undergoes cell death. p53 is an apoptosis regulator, an interphase mode of cell death frequent in hematopoietic cell lineages. Myosin proteins are found in cardiac tissues; CD45 is a type I transmembrane protein that is present in various isoforms on all differentiated hematopoietic cells, Protein C is blood coagulation factor.

Reference:  

208. In NHEJ, which DNA repair protein with endonuclease activity is involved in processing strand breaks prior to DNA ligation?

E. RPA  
F. Artemis  
G. Rad51  
H. MDC1  

Key: B  

Rationale:  
Exposure of cells to ionizing radiation or radiomimetic drugs generates DNA double-strand breaks that are processed either by homologous recombination repair (HRR), or by canonical, DNA-PKcs-dependent non-homologous end-joining (C-NHEJ). There is evidence for the involvement of Artemis endonuclease, a protein deficient in a human radiosensitivity syndrome associated with severe immunodeficiency (RS-SCID), in the processing of subsets of DSBs by HRR or C-NHEJ. It is thought that within HRR or C-NHEJ Artemis processes DNA termini at complex DSBs. Cells deficient in Artemis are more sensitive than normal cells to X-rays. Artemis can remove damaged ends from DNA. However, evidence that both ATM and Artemis are specifically required for repair of DSBs in heterochromatin. Rad51 and RPA function in the homologous recombination repair (HRR) pathway and MDC1 protein is a regulator of the Intra-S phase and the G2/M cell cycle checkpoints and also recruits repair proteins to the site of DNA damage.

Reference:  
209. Which of the following nuclei is likely to be the MOST stable?

A. $^{92}_{42}$Mo
B. $^{78}_{39}$Y
C. $^{161}_{60}$Nd
D. $^{194}_{78}$Pt

**Key:** D

**Rationale:**
For atomic number $Z \geq 20$, the most stable nuclei have more neutrons than protons and an even number of each. Choice A has more protons than neutrons. Choice B has an equal number of neutrons and protons and an odd number of each. Choice C has more neutrons than protons, an even number of protons but an odd number of neutrons. Choice D has more neutrons than protons and an even number of each.

**Reference:**

210. What is the main rationale for using deep inspiration breath hold (DIBH) in breast treatments?

A. Decreased dose inhomogeneity
B. Decreased breast separation
C. Increased heart sparing
D. Increased esophagus sparing

**Key:** C

**Rationale:**
DIBH increases the amount of air in the lung, which moves the breast farther away from the heart, resulting in increased heart sparing.

**Reference:**
A 15-year-old boy with intermediate risk stage II Hodgkin lymphoma of the neck and mediastinum undergoes 4 cycles of ABVE-PC chemotherapy. After 2 cycles of chemotherapy the product of perpendicular diameters of this disease reduces by more than 60% in all sites of disease. After 4 cycles of chemotherapy, all involved lymph nodes have returned to dimensions within normal limits. End of chemotherapy PET-CT showed all disease was Deauville 2 or lower. What is the MOST appropriate next step in his management?

A. No radiation  
B. 15 Gy in 10 fx  
C. 21 Gy in 14 fx  
D. 30 Gy in 20 fx

Key: A

Rationale:
AHOD0031 established that patients who achieved these response criteria (80% reduction in product of perpendicular diameters in all sites of disease at the end of chemotherapy can be substituted for return to node size within normal limits) do not need to receive adjuvant radiation therapy.

Reference:  

212. Which isotope is used in positron emission tomography (PET)?

A. $^{18}\text{F}$  
B. $^{60}\text{Co}$  
C. $^{131}\text{I}$  
D. $^{192}\text{Ir}$

Key: A

Rationale:
$^{18}\text{F}$ produces a positron appropriate for use in PET imaging. $^{60}\text{Co}$ produces high energy gamma rays appropriate for use in teletherapy. $^{131}\text{I}$ produces both beta and gamma radiation and is appropriate for local therapy or imaging studies. $^{192}\text{Ir}$ produces gamma rays appropriate for use in brachytherapy.

Reference:  
213. The overall RBE factor of a proton therapy beam is:

   A. 1.0
   B. 1.1
   C. 1.3
   D. 1.8

**Key:** B

**Rationale:**
Clinical use of protons utilizes a spread out Bragg peak, giving an RNE of 1.1. The RBE of a proton therapy beam is recommended to be 1.1 based on the ICRU-78.

**Reference:**

214. What proteins coat single strand DNA to prevent replication fork collapse in HRR?

   A. RAD51
   B. ATRIP
   C. RPA
   D. γH2AX

**Key:** C

**Rationale:**
RPA is the single strand DNA binding protein that coats single strand DNA during replication and protects DNA during strand insertion in HRR. Phosphorylated H2AX is a marker of a radiation-induced DNA double-strand break. ATRIP is an ATR-interacting protein partner which is an essential component of the DNA damage checkpoint pathway and is required to localize ATR to sites of DNA damage. RAD51 is a central protein involved in homologous recombination repair (HRR) of DNA double-strand breaks (DSBs) that is involved in the search for homology and strand pairing stages of the process.

**Reference:**
215. What is the MOST common location of Ewing sarcoma?

A. Spine  
B. Pelvis  
C. Femur  
D. Humerus  

Key: B  

Rationale:  
25% of Ewing sarcoma arises in the pelvis, followed by femur (16%) and ribs (12%). Humerus (5%) and spine (8%) are less common.

Reference:  

216. What is the definitive radiation dose for stage I lymphoma involving mucosa-associated lymphoid tissue (MALT) of the left parotid gland?

A. 24 Gy  
B. 36 Gy  
C. 45 Gy  
D. 50.4 Gy  

Key: A  

Rationale:  

Reference:  
217. A 12-year-old girl with a 4 cm alveolar rhabdomyosarcoma of the extremity without nodal or distant metastases has a partial response to induction chemotherapy. What is her disease Group?

A. I  
B. II  
C. III  
D. IV

Key: C

Rationale:
Group is defined after biopsy or surgery and before starting chemotherapy. This patient had gross disease at the time of starting chemotherapy, therefore she had Group III disease. Group I patients have no gross or microscopic disease; Group II patients have microscopic or lymphatic disease (or both); Group IV patients have metastatic disease.

Reference:

218. What did the pooled analysis of two Phase 3 studies (STARS and ROSEL) examining SBRT versus surgery for early stage NSCLC demonstrate?

A. Superior OS favoring surgery  
B. Similar OS between surgery and SBRT  
C. Significantly lower grade 3-4 toxicity events with SBRT  
D. Similar grade 3-4 toxicity events between surgery and SBRT

Key: C

Rationale:
In the pooled analysis of STARS and ROSEL phase 3 trials, estimated overall survival at 3 years was 95% in the SABR group compared with 79% (p=0.037) in the surgical arm. Recurrence-free survival at 3 years was 86% (95% CI 74-100) in the SABR group and 80% (65-97) in the surgery group (HR 0.69 [95% CI 0.21-2.29], log-rank p=0.54). Grade 3-4 toxicity rates were 44% in the surgery arm versus 10% in the SABR arm. In the surgery group, one (4%) patient died of surgical complications.

Reference:
219. High LET radiation be beneficial over low LET X-rays in treating tumors under which environmental constraint?

A. Hypoxia  
B. Hyperthermia  
C. High vascularization  
D. Low inflammation

**Key:** A

**Rationale:**
Hypoxic tumors are more resistant to low LET radiation due to the oxygen effect. The presence of oxygen is required to mediate 2/3 of cell killing effect via indirect damage. Also, the oxygen effect is most commonly explained by the oxygen fixation hypothesis, which postulates that radical-induced DNA damage can be permanently 'fixed' by molecular oxygen, rendering DNA damage irreparable. For High LET radiation, damage is predominantly attributable to direct effects in DNA, and with no or less oxygen available the 'fixation' of DNA damage by molecular oxygen that renders DNA damage irreparable does not occur and damage can be repaired, ergo, cells are more resistant to killing in the absence of oxygen.

**Reference:**

220. In the HD 16 randomized control trial comparing the role of radiotherapy for favorable Hodgkin patients that have negative PET scans (defined as Deuville score < 3) after 2 cycles of ABVD, what was the impact of RT?

A. Increased PFS and OS  
B. Increased PFS but not OS  
C. Increased PFS but decreased OS  
D. Increased PFS and OS

**Key:** B

**Rationale:**
Radiotherapy improved PFS at 5 years from 88.4% to 93.2% (p = 0.047) for PET 2 negative patients (i.e, those with Deuville score < 3); No difference was noted in OS. Thus, radiotherapy should can not be removed from CMT for PET 2 negative without relevant loss in tumor control.

**Reference:**
221. In ICRU-83, what is the planning organ at risk volume (PRV)?

A. Volume to account for motion of the target next to an organ at risk
B. Volume to account for uncertainties and variations in position of a specific organ
C. Volume that delineates the portion of an organ that is most at risk
D. Volume of a parallel organ that is critical for radiation injury

**Key:** B

**Rationale:**
The PRV is an organ specific volume that is generated by a margin expansion of the organ volume to account for uncertainties and variation in the position of the organ during treatment.

**Reference:**

222. According to the German High-Grade NHL Study Group, DLBCL involving which organ may predict increased risk for CNS relapse?

A. Lung
B. Heart
C. Bowel
D. Adrenal Gland

**Key:** D

**Rationale:**
The German High-Grade Non-Hodgkin’s Study Group proposed prognostic model to predict the risk of CNS replace and incorporated the following 5 factors (age > 60, LDH > normal, stage III/IV, ECOG PS>1 and involvement of the kidney or adrenal gland). Rate of relapse at 2 yrs varied from less than or equal to 1% up to 17% with 4 or 5 factors. Thus, lumbar puncture should be considered in patients with 4-6 risk factors. Other risk factors also include greater than or equal to 2 extranodal sites, involvement of testes, paranasal sinuses, and bone marrow.

**Reference:**
223. What is the recommended treatment for a 45-year-old patient with refractory Hodgkin lymphoma involving the mediastinum, who has a complete response by PET/CT scan to 2nd line chemotherapy?

A. Surgery alone  
B. Radiation alone  
C. High dose chemotherapy + allogeneic SCT  
D. High dose chemotherapy + autologous SCT

**Key:** D  

**Rationale:**  
Per ILROG, the standard of care is HDT & autologous SCT.

**Rationale:**  

224. Radical surgery with an extrapleural pneumonectomy or extended pleurectomy with decortication would be acceptable for which of the following patients with malignant pleural mesothelioma?

A. T3N2M0 epithelioid mesothelioma involving the mediastinal fat and pericardium  
B. T2N0M0 sarcomatoid mesothelioma involving the diaphragm  
C. T3N0M0 epithelioid mesothelioma involving the endothoracic fascia and chest wall involvement  
D. T4N1M0 biphasic mesothelioma involving the myocardium, vertebral body, and multiple ribs

**Key:** C  

**Rationale:**  
Due to the morbidity of the surgery, appropriate patient selection for radical surgery is critical for patients with malignant pleural mesothelioma. Patients frequently not considered for radical surgery due to poor long-term outcomes are those with sarcomatoid or biphasic histology, N2 or N3 disease, distant metastases, or T4 disease. Per NCCN guidelines, there continues to be controversy regarding choice of surgical procedure (EPP vs P/D) for early-stage disease (confined to the pleural envelope with no N2 nodal involvement) with favorable histology (epithelioid)

**Reference:**  
225. In which patient could omission of whole lung radiotherapy in the upfront management of Wilms tumor be considered?

A. 3 year old with pulmonary and osseous metastatic disease who has a rapid complete response following 6 weeks of chemotherapy
B. 5 year old with pulmonary only metastatic disease who has a rapid complete response and LOH for 1p and 16q
C. 10 year old with pulmonary only metastatic disease who has a rapid complete response and no LOH for 1p or 16q
D. 4 year old with pulmonary only metastatic disease who has a slow incomplete response and no LOH for 1p or 16q

Key: C

Rationale:
The requirements for omission of whole lung irradiation in AREN0533 include rapid complete response following week 6 of chemotherapy, favorable histology, absence of LOH for 1p & 16q, and lung only metastatic disease. While the trial was risk adapted based on LOH 1p and 16q status, an additional post-hoc analysis was conducted evaluating the prognostic utility of 1q gain. Patients with pulmonary CR and 1q gain had significantly reduced EFS relative to those without 1q gain. Patient with 1q with lung CR treated without RT had predominately lung failures (9/11 patients). These criteria will likely be used to inform future RT omission strategies in favorable histology Wilms tumor.

Reference:
226. On a LOG-LIN clonogenic survival plot, what does a linear survival curve for a mammalian cell line indicate?

A. High level of hypoxic stress  
B. Absence of DNA repair  
C. Irradiation with low LET radiation  
D. Large beta component of cell kill

**Key:**  B

**Rationale:**
When plotted on a LOG-LIN scale, the survival curve of a repair-competent mammalian cell line measured using a colony assay is typically shouldered. The shoulder is generally considered as indicative of the ability to accumulation and repair of sub-lethal DNA lesions. The absence of a shoulder translates to a linear survival curve, and linear survival can represent cell lines that show an absence of repair, or cell lines with repair defects in pathways of radiation repair mechanisms (e.g. ATM, Ligase IV). A large beta component of cell kill is associated with a bendy or shouldered survival curve, beta is generally regarded to reflect reparability in the LQ model. A low LET survival curve would be shouldered because of repair of sublethal lesions.

**Reference:**
227. In a pediatric patient with isolated testicular relapse of B-cell ALL treated with methotrexate-based salvage chemotherapy, what are the minimum criteria for consideration of omission of testicular RT?

A. Relapse > 9 months after first remission, with negative testicular biopsy after chemotherapy
B. Relapse > 12 months after first remission, with negative testicular biopsy after chemotherapy
C. Relapse > 15 months after first remission, with resolution of testicular swelling after chemotherapy
D. Relapse > 18 months after first remission, with resolution of testicular swelling after chemotherapy

Key: D

Rationale:
Omission of testicular RT is an acceptable option in ALL patients with an isolated testicular relapse who relapse 18 months or longer following their first clinical remission, and achieve clinical or pathologic complete remission (either resolution of the testicular swelling or are negative by biopsy in the testes) following high dose methotrexate based salvage induction chemotherapy (as per AALL02P2). If the degree of resolution of testicular swelling is indeterminate, a biopsy may be performed. If the biopsy confirms a lack of leukemic cells, testicular RT may be omitted despite the indeterminate clinical resolution of testicular swelling.

Reference:

228. Which of the following RT imaging systems is MOST suitable to monitor prostate motion during treatment?

A. Stereoscopic kV x-rays system
B. Surface imaging system
C. MR-Linac imaging system
D. MV CBCT imaging system

Key: C

Rationale:
A MV CBCT imaging system will not provide intra-fraction motion monitoring. Surface imaging can use the patient surface as a surrogate to monitor real-time but does not actually monitor the prostate. A stereoscopic kV x-ray system may be able to monitor the prostate but will require the need of fiducials to be implanted. Monitoring frequency is typically at 15-30secs. A MR-linac system would be most suitable to monitor prostate motion during treatment due to its ability to visualize the prostate without fiducials and at a much faster frequency of 200-600 milliseconds.

Reference:
229. What was the main finding of the United Kingdom (BNLI NCRI) reduced dose Phase III randomized control trial for follicular and marginal zone lymphoma, that compared 45 Gy against 24 Gy?

A. 45 Gy had better freedom from local progression, PFS, and OS
B. 45 Gy had worse freedom from local progression, PFS, and OS
C. 24 Gy had equal freedom from local progression, PFS, and OS
D. 24 Gy had better freedom from local progression, PFS, and OS

Key: C

Rationale:
There was no significant difference in clinical outcomes between the groups. There was more erythema in the higher dose RT arm; This phase III randomized trial, helped lower doses for follicular and marginal zone lymphoma.

Reference:
Radiotherapy Oncology, 100; 2011; Lowry L et al. page 86-92.

230. What protein inhibits Cyclin B/CDK1 interaction and G2 to M transition?

A. p38
B. Wee1
C. p21
D. CDC25A

Key: B

Rationale:
Wee1 is a nuclear kinase belonging to the Ser/Thr family of protein kinases. Wee1 has a molecular mass of 96 kDa and it is a key regulator of cell cycle progression. It influences cell size by inhibiting the entry into mitosis, through inhibiting Cdk1. Wee1 is a tyrosine kinase that is known to be overexpressed in many cancer types such as luminal and HER2-positive breast cancer subtypes, hepatocellular carcinomas, and glioblastomas (Iorns et al., 2009). It regulates the G2-M transition by phosphorylating CDK2 to inactivate the CDK2/cyclin B complex to terminate the cell cycle. The G2 checkpoint is critical for premitotic DNA repair.

Reference:
231. What ATM-mediated epigenetic modification of histones occurs immediately after the production of radiation-mediated double strand breaks in DNA?

A. Phosphorylation  
B. Acetylation  
C. Glycosylation  
D. Methylation

**Key:** A

**Rationale:**
Epigenetic regulation of genes can occur at the level of the histone proteins intimately associated with the DNA. Modification of the histones that surround the DNA can lead to complex signaling that directs the packing and unpacking of the DNA double helix. Epigenetic regulation of histones can occur through acetylation, phosphorylation, methylation and ubiquitination. Phosphorylation of H2AX – gammaH2AX is a molecular marker of radiation-induced DNA double strand breaks that occurs with minutes after irradiation; and prior to strand annealing.

**Reference:**

232. In a clonogenic survival assay, a sample of 200 cells was exposed to radiation before plating and a sample of 100 cells was exposed to control treatment (no irradiation). At the end of the assay, 40 colonies were counted in the irradiated sample and 80 colonies were counted in the control sample. What was the percent survival in the irradiated cells?

A. 10%  
B. 25%  
C. 50%  
D. 75%

**Key:** B

**Rationale:**
The plating efficiency of the unirradiated cells was 80/100 = 0.8. In the irradiated sample, 40 cells out of 200 formed a colony (40/200 = 0.2). Taking plating efficiency into account, the percent survival of the irradiated cells was 0.2/0.8=25%.

**Reference:**
233. Based on results of the randomized Phase II study of local consolidative therapy versus maintenance therapy or observation (Gomez et al.) for patients with oligometastatic NSCLC (≤3 lesions), local consolidative therapy was associated with all the following EXCEPT:

A. Improved PFS  
B. Improved OS  
C. Increased grade 4+ toxicity  
D. Increased time to appearance of new lesions  

Key: C

Rationale:
Local consolidative therapy versus maintenance therapy or observation improved median PFS (14.2 vs. 4.4 months, P=0.022), median OS (41.2 vs. 17.0 months, p=0.017), and time to appearance of new lesions (14.2 vs. 6.0 months, P=0.11). There were no grade 4 or 5 adverse events associated with treatment.

Reference:

234. Which of the following statements best describe the current best practice for the management of SCLC?

A. Stage I SCLC can be managed by lobectomy followed by adjuvant chemotherapy  
B. 60-70 Gy concurrent with chemotherapy is preferred for limited stage SCLC due to its lower toxicity  
C. PCI is strongly recommended for extensive stage SCLC responding to chemotherapy  
D. Consolidation radiation to 45 Gy in 15 fractions is recommended after chemotherapy without progression in extensive stage SCLC  

Key: A

Rationale:
Based on NCCN 2019 guidelines, stage I SCLC in a resectable patient should be managed with a lobectomy followed by adjuvant chemotherapy. In unresectable patient, SBRT could be considered followed by chemotherapy. Choice B is incorrect since the Turrisi regimen (45 Gy in 30 fx at 1.5 Gy BID) is still the standard of care regimen but 60-70 Gy is also allowed but not because it is less toxic but because it seems to be equivalent to the Turrisi regimen. Choice C is incorrect since it is now controversial if PCI is beneficial for extensive stage SCLC based on the Takahashi RCT from Japan with MRI surveillance. Choice D is incorrect since 30 Gy in 10 fx is the recommended consolidation dose based on the EORTC study (Slotman et al., Lancet 2015).

Reference:
NCCN 2019 Guidelines.
235. What is the histology of the MOST common pediatric brain tumor?

A. Medulloblastoma  
B. Ependymoma  
C. Meningioma  
D. Pilocytic astrocytoma

**Key:** D

**Rationale:**  
Brain tumors are the most common solid malignancy in children. About half of all pediatric brain tumors are gliomas; one-third of these are pilocytic astrocytomas. Embryonal tumors, of which medulloblastoma is the most common, only account for 15% of pediatric brain tumors.

**Reference:**  

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236. A patient’s spine is treated with a single 17 cm long by 7 cm wide posterior-anterior (PA), 6 MV beam with a SSD = 100 cm. The dose delivered to a depth of 5.0 cm is 180 cGy. Use the percent depth dose table below for 6 MV to calculate the dose at a depth of 10 cm.

<table>
<thead>
<tr>
<th>Field Size (cm)</th>
<th>Depth (cm)</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>84.9</td>
<td>86.9</td>
<td>87.9</td>
<td>88.3</td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>63.9</td>
<td>67.6</td>
<td>70.0</td>
<td>71.6</td>
<td></td>
</tr>
</tbody>
</table>

A. 122 cGy  
B. 140 cGy  
C. 148 cGy  
D. 154 cGy

**Key:** B

**Rationale:**  
The equivalent square field size is approximately 10 cm. The dose at a depth of 10 cm is the dose at a depth of 5 cm multiplied by the ratio of depth doses: \(180 \times \frac{67.6}{86.9} = 140\).

**Reference:**  
237. The delivery of volumetric-modulated arc therapy (VMAT) is BEST described by which of the following?

A. Large number of treatment fields which treat a target volume with multiple MLC-defined subfields per treatment field
B. Large number of treatment fields which treat a target volume with the MLC of each treatment field sweeping across the target volume
C. An arc treatment field that uses the MLC to dynamically conform to the target volume shape at set angular intervals (i.e. 5°)
D. An arc treatment field that uses the MLC to dynamically shape the radiation field to optimizer-defined shapes at set angular intervals (i.e. 5°)

Key: D

Rationale:
Volumetric-modulated arc therapy (VMAT) is a technique that uses the MLC dynamically to shape the fields as the gantry rotates through an arc. The fields are not necessarily conforming to the target volume but are rather pre-determined by the optimizer.

Reference:

238. The risk of a parent with retinoblastoma having a child with retinoblastoma is:

A. 1% if a parent with unilateral disease has a positive family history.
B. 5% if a parent with bilateral disease has a negative family history.
C. 20% if a parent with bilateral disease has a positive family history.
D. 45% if a parent with unilateral disease has a positive family history.

Key: D

Rationale:
Retinoblastoma is a classic example of how the poisson distribution dictates the inheritance patterns seen in patients with sporadic or germline RB1 mutations. The hypothesis put forward by A.G. Knudsen Jr specified that Retinoblastoma occurred following two mutational events. In the dominantly inherited form, one mutation is inherited via the germinal cells and the second occurs in somatic cells. In the nonhereditary form, both mutations occur in somatic cells. A child born from a parent with bilateral disease or a parent with unilateral disease and a positive family history has a 45% risk of developing retinoblastoma. A child born from a parent with unilateral disease and no family history has a less than 2% chance of developing retinoblastoma, however this risk becomes 45% with a positive family history.

Reference:
239. What is the approximate difference in imaging dose to the brain for a patient aligned by two orthogonal 6 MV portal images as compared to a kV cone-beam CT (kV-CBCT)?

A. MV portal imaging deposits 5x more dose than a kV-CBCT
B. MV portal imaging deposits 2x more dose than a kV-CBCT
C. MV portal imaging deposits 2x less dose than a kV-CBCT
D. MV portal imaging deposits 5x less dose than a kV-CBCT

Key: A

Rationale:
6 MV portal pairs for skull imaging impart 2-5 cGy, roughly proportional to the MU used assuming a standard calibration (2 MU per port, two port images). Modern kilovoltage cone-beam CT techniques impart approximately 0.5 cGy to soft tissues in the brain. While there will be variations depending on the actual use case, it is reasonable to say in a typical scenario megavoltage orthogonal portal images impart approximately five times more dose than a kilovoltage cone-beam CT.

Reference:

240. How do pro-apoptotic BCL-2 proteins facilitate apoptosis?

A. Inducing oligomerization of BAX or BAK
B. Activating caspase-3
C. Enhancing p53 signal transduction
D. Oligomerizing XIAP or c-IAP1

Key: A

Rationale:
The pro-apoptotic BCL-2 proteins aide with the oligomerization of BAX or BAK. These proteins, if oligomerized, form pores in the mitochondrial outer membrane allowing the release of cytochrome c into the cytoplasm. Once there, cytochrome c combines with APAF1 to form the apoptosome which activates caspase-9. This in turn starts a cascade which activates several other caspases, the work horses of apoptosis. Caspase 3 is pro-apoptotic but functions downstream of BCL-1/BAX/BAK; P53 signaling is an upstream event and activates BCL-2. XIAP (X-linked inhibitor of apoptosis protein) and c-IAP1 are inhibitors of apoptosis.

Reference:
241. In patients with relapsed localized DLBCL, what response to 2\textsuperscript{nd} line of chemotherapy would likely have the GREATEST benefit with the addition of pre-transplant RT?

A. Pre-transplant RT is not usually recommended
B. CR by PET and CT
C. CR by PET but PR by CT
D. PR by PET and CT

Key: D

Rationale:
Patients with a PR by PET to 2\textsuperscript{nd} line chemotherapy do poorly and should receive pre-transplant RT. Peri-transplant RT can potentially cytoreduce localized residual disease before HDT-ASCT. Most studies have shown that patients with relapsed/refractory NHL undergoing HDT-ASCT, and then received RT had improved outcome. Data on peritransplant RT for CR after salvage chemotherapy is limited because most of the studies were from the pre-PET era.

Reference:

242. What advantage does MV portal imaging offer when compared to kV planar imaging?

A. It allows for better soft tissue contrast for kV portal imaging
B. It delivers a lower imaging dose than kV planar imaging
C. It allows for the visualization of the treatment field with blocking
D. It is uniquely capable of verifying that the patient is setup to isocenter

Key: C

Rationale:
Since MV portal imaging uses the treatment beam, the image shows exactly how the patient anatomy is positioned relative to the field shape. Option A is incorrect since kV gives better soft tissue contrast. Option B is incorrect since MV portal imaging gives a higher imaging dose than kV portal imaging. Option D is wrong since kV portal imaging also can verify isocenter.

Reference:
243. Why is a Geiger Mueller counter used to survey during a prostate seed implant procedure?

A. High radiation sensitivity
B. Ability to paralyze at high exposure rates
C. Provides quantitative readings to release the patient
D. Ability to detect photon energy differences

Key:  A

Rationale:
Geiger Mueller counters have high sensitivity, and therefore can detect loose seeds having low activity, which is their primary use during prostate seed implants. These counters paralyze at high exposure rates, which is a disadvantage, but this limitation occurs at much higher exposure rates than those resulting from a prostate seed implant. Geiger Mueller counters measure counts per minute, and thus do not quantitatively measure exposure rates for releasing patients.

Reference:

244. What is the typical maximum energy of protons accelerated in a modern cyclotron used for therapeutic RT?

A. 75 MeV
B. 125 MeV
C. 250 MeV
D. 500 MeV

Key:  C

Rationale:
Modern day cyclotrons for radiotherapy accelerate protons to 250 MeV (range of ~33cm in water).

Reference:
245. Why is the mass collision stopping power, $S_{\rho}$, for electrons with a given speed is higher for water than for tungsten?

A. Tungsten has a higher mass density (g/cm$^3$)
B. Radiative interactions are more likely in tungsten
C. Water has a larger electron density (electrons/gm) than tungsten
D. More delta rays are produced by electrons in water than in tungsten

Key: C

Rationale:
Although the collisional stopping power is greater for tungsten than for water, the mass collision stopping power is lower. The mass collision stopping power is proportional to the electron density (electrons/gm) of the medium and inversely proportional to the square of the speed of the bombarding charged particle. The electron density is in turn proportional to $Z/A_W$ where $Z$ is the atomic number and $A_W$ is the atomic weight (g/mole). This quantity declines slightly with increasing atomic number (for $Z > 1$).

Reference:

246. A 45-year-old patient presenting with chest pain was found to have a large anterior mediastinal mass. What elements of the H&P may suggest a diagnosis of thymoma?

A. Weight loss
B. Blurry vision towards end of the day
C. Dehydration
D. Motor weakness that improves with exertion

Key: B

Rationale:
Paraneoplastic syndrome associated with thymomas are myasthenia gravis, red cell aplasia, hypogammaglobulinemia. Choice A is incorrect since it may be associated with B symptoms along with fevers in patients with lymphomas. Choice B is correct since it is one of the signs related to myasthenia gravis (ptosis, diplopia) along with motor weakness and easy fatigability. Choice C is incorrect since this is associated with SIADH for patients with small cell lung cancer in a patient with mediastinal mass. Choice D is incorrect since this is more a sign of Lambert Eaton Syndrome, with proximal muscle weakness that can improve with exertion. Lambert Eaton could be associated with small cell lung cancer.

Reference:
NCCN 2019 Guidelines.
247. According to International Lymphoma Radiation Oncology Group (ILROG) guidelines what is the recommended total prescription dose range for solitary bone plasmacytoma measuring less than 5 cm?

A. 30-35 Gy  
B. 35-40 Gy  
C. 40-45 Gy  
D. 45-50 Gy

**Key:** B

**Rationale:**
ILROG recommends a total of 35-40 Gy for solitary bone plasmacytoma measuring <5 cm and 40-50 Gy if measuring >5 cm.

**Reference:**

248. The likelihood of nodular lymphocyte predominant Hodgkin lymphoma (NLPHL) transforming to higher grade DLBCL is in the range of:

A. 0-5%  
B. 10-15%  
C. 20-25%  
D. 30-35%

**Key:** A

**Rationale:**
NLPHL only involves the mediastinum in 5% of cases, more commonly involving axillary or cervical nodes. NLPHL represents only 5% of all Hodgkin lymphoma cases and is CD15- CD30- CD20+. It transforms to diffuse large B cell lymphoma in 3-5% of cases.

**Reference:**
249. An 8-year-old patient with embryonal rhabdomyosarcoma has five lung metastases measuring 0.5 to 1.5 cm at presentation that respond completely to induction chemotherapy. What is the most appropriate approach for his lung metastases as part of consolidation therapy?

A. No radiation
B. 10 Gy in 5 fx to both whole lungs
C. 15 Gy in 10 fx to both whole lungs
D. 30 Gy in 6 fx to each lung metastasis

**Key:** C

**Rationale:**
Patients with lung metastases should receive whole lung irradiation, 15 Gy in 10 fractions. Robeberg, et al, showed patients receiving whole lung irradiation were less likely to have lung recurrences. Whole lung irradiation is often deferred until the end of systemic therapy because it can contribute to myelosuppression.

**Reference:**

250. In a patient with metastatic high-risk neuroblastoma after GTR of the primary site and CR of all metastatic sites, what is the most appropriate management of the primary site?

A. No radiation
B. 21.6 Gy in 12 fx
C. 36 Gy in 20 fx
D. 45 Gy in 25 fx

**Key:** B

**Rationale:**
CCG-3891 established role of approximately 20 Gy improving the probability of local control in patients with high risk neuroblastoma.

**Reference:**
251. What alterations of blood flow to the tumor would result in the GREATEST therapeutic gain with RT?

A. Reduced flow in tumor
B. Elevated flow in tumor
C. No effect
D. Intermittent flow

**Key:** B

**Rationale:**
Increasing the blood flow to the tumor would potentially result in radiosensitization because the level of oxygen in the tumor is increased. Oxygen is involved with cell killing effect via indirect damage effects on DNA. Also, the radiosensitizing effects of oxygen is most commonly explained by the oxygen fixation hypothesis, which postulates that radical-induced DNA damage can be permanently ‘fixed’ by molecular oxygen, rendering DNA damage irreparable leading to more tumor cell killing and increasing the therapeutic ratio. Conversely, decreasing blood flow to tumors could cause radiation resistance by increasing hypoxia and with no or less oxygen available the ‘fixation’ of DNA damage by molecular oxygen that renders DNA damage irreparable does not occur and DNA damage can be repaired, ergo, cells are more resistant to killing in the absence of oxygen.

**Reference:**

252. What is the grade of a follicular lymphoma that has 0-5 large B cells per high power field?

A. 0
B. 1
C. 2
D. 3

**Key:** B

**Rationale:**
FL are the second most common type of NHL, and represents 22% of all cases. They are typically considered low grade lymphoma, unless there is grade 3B, which are treated like DLBCL. They are tumors of follicle center B cells and contain centrocytes and centroblasts (C) with a follicular (nodular) pattern. Grading depends on (WHO Classification) number of LARGE cells per high power field (0-5, 5-15, or > 15). Grade 1 includes 0-5 large cells per higher power field, grade 2 includes 6-15, and grade 3A and 3B included > 15 large cells per higher power field. The difference between 3A and 3B include the absence or presence (A) or absence of centrocytes (B).

**Reference:**
253. On the DAHANCA study, what hypoxic cell radiosensitizer was given without major side-effects and produced significant improvement in both LRC and OS compared with radiotherapy alone in supraglottic and pharyngeal carcinomas?

A. Metronidazole  
B. Misonidazole  
C. Etanidazole  
D. Nimorazole

Key: D

Rationale:
A randomized double-blind phase III study of nimorazole as a hypoxic radiosensitizer of primary radiotherapy in supraglottic larynx and pharynx carcinoma. Results of the Danish Head and Neck Cancer Study (DAHANCA) Protocol 5-85 showed Nimorazole significantly improves the effect of radiotherapeutic management of supraglottic and pharynx tumors and can be given without major side-effects. Metronidazole, Misonidazole and Etanidazole can be regarded as better radio sensitizers but they are associated with more toxicity; Nimorazole is a less effective radiosensitizer but has a better toxicity profile.

Reference:

254. Which of the following describes beta-plus nuclear decay?

A. A proton becomes a neutron, creating a positron and neutrino  
B. A proton becomes a neutron, creating a positron and antineutrino  
C. A neutron becomes a proton, creating a positron and neutrino  
D. A neutron becomes a proton, creating a positron and antineutrino

Key: A

Rationale:
Beta-plus or positron decay occurs when the neutron-to-proton (n/p) ratio of the nucleus is below that to achieve nuclear stability. To create a more stable nucleus, a proton transforms into a neutron thereby increasing the ratio. To conserve charge, a positron is created. To conserve spin/angular momentum, a neutrino is created.

Reference:
255. Which of the following mutations is associated with lack of responsiveness to conventional EGFR TKI therapy?

A. Exon 19 deletions  
B. T790M  
C. TP53  
D. ALK  

**Key:** B

**Rationale:**
Most EGFR exon 20 insertions and p.T790M are associated with lack of responsiveness to conventional EGFR TKI. Osimertinib is recommended for patients with T790M positive tumors progressed on first line EGFR TKI. Many modern generation EGFR TKIs like Osimertinib also have excellent intracranial activity and are recommended for all EGFR mutation positive brain metastases irrespective of T790M status.

**Reference:**

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256. In a report from the Childhood Cancer Survivor Study, what was the MOST significant factor associated with secondary sarcoma development after treatment of childhood cancer?

A. Radiation dose  
B. Anthracycline exposure  
C. Age at treatment  
D. Gender  

**Key:** A

**Rationale:**
Radiation exposure was the most significant factor associated with development of a secondary sarcoma, with a dose-response relationship starting at doses as low as 10 Gy.

**Reference:**
257. How much additional storage space is required for a 512 x 512, 12-bit image as compared to a 256 x 256, 8-bit image?

A. 4x more  
B. 6x more  
C. 16x more  
D. 64x more

Key: D

Rationale:
Data storage requirements are proportional to the number of pixels in an image and number of possible image values (bits) per pixel. As such this will be \( \frac{512 \times 512 \times 2^{12}}{256 \times 256 \times 2^{8}} = 64 \).

Reference:
Bushberg et al. The Essential Physics of Medical Imaging, 3rd Edition, Lippincott Williams & Wilkins, 2012, pg. 150-152

258. Which linear accelerator head component is necessary when delivering an electron beam?

A. Target  
B. Scattering foil  
C. Multi-leaf collimator (MLC)  
D. Jaw collimators

Key: B

Rationale:
The scattering foil is used to spread out the narrow electron beam in which the electrons were accelerated in the accelerating structure. A target is only used to generate photons when used in photon mode. A collimator is used to shape a photon field but not an electron field.

Reference:
259. In patients with limited-stage SCLC undergoing PCI, when compared with higher dose (36 Gy), use of 25 Gy in 10 fx resulted in:

A. higher incidence of brain metastases.
B. comparable cancer-related mortality.
C. comparable toxicity.
D. lower OS.

Key: C

Rationale:
In this international randomized study, patients with limited-stage SCLC in complete remission after chemotherapy and thoracic radiotherapy were randomly assigned to a standard PCI dose group (25 Gy in 10 fractions) or higher-dose (36 Gy in 18 once-daily 2 Gy or 24 twice-daily 1.5 Gy fractions). Upon final analyses, there was no significant difference in the 2-year incidence of brain metastases between the standard and the higher-dose group, at 29% and 23%, respectively (p=0.18). When brain metastasis is considered as an isolated first site of failure, the HR is 0.48 (0.29–0.81, p=0.005) and the 2-year difference is also 6% (12% vs 6% favoring the higher dose group). Two-year overall survival was 42% in the standard-dose group and 37% in the higher-dose group (p=0.05). Two-year disease-free survival was 33% in the standard-dose group and 29% in the higher-dose group (p=0.1). The lower overall survival in the higher-dose group is probably due to increased cancer-related mortality. No significant differences in toxicity were noted between the two groups.

Reference:

260. Which translocation is associated with a FAILURE of antibiotic therapy for H.pyloric eradication for gastric MALT?

A. t(10;14)
B. t(11;18)
C. t(14;18)
D. t(9;22)

Key: B

Rationale:
The presence of translocation t(11:18) (q21;q21) is a feature associated with poor response to H.pylori eradication for gastric MALT. All others are not related to gastric MALT antibiotic resistance. Others things that are potentially associated with resistance include BCL10 and NF-KB.

Reference:
261. During CT simulation, the field of view (FOV) should be optimized in order to:

A. reduce patient dose.
B. reduce scattered radiation.
C. ensure optimal scanning time.
D. ensure accurate external contour of the patient.

Key: D

Rationale:
During CT simulation, the FOV should be selected to ensure that the external contour of the patient is acquired in the CT dataset. This is important as it is used in the treatment planning system for accurate dose calculation, and it may also be necessary to help during the IGRT alignment process.

Reference:

262. In record and verify systems, what is the primary reason behind having a system of user rights that vary among different types of users (e.g. physician, dosimetrist, therapist, etc)?

A. Limit users from safely stopping treatment in an emergency
B. Limit users from viewing patient records
C. Allow users to override all treatment parameters
D. Allow users to safely perform their specific job functions

Key: D

Rationale:
User rights are set up to allow users to perform their standard job functions, while also limit them from accidentally making changes that can affect treatment accuracy. For example, therapists may have user rights to override couch translational limits during treatment, as this action may be needed during normal situations. Therapists, however, might not have user rights to override the MU to be delivered, as this action is not typically needed during treatment and will result in a deviation in delivered dose.

Reference:
263. Based on secondary analysis (Chun et al.) of RTOG 0617 study, all the following factors were associated with grade 3+ radiation pneumonitis with definitive cheoRT for stage III NSCLC EXCEPT:

A. Lung V5
B. Lung V20
C. Radiation technique (3D conformal RT vs. IMRT)
D. AJCC Stage Group (IIIA vs. IIIB)

Key: A

Rationale:
Based on multivariate analysis of RTOG 0617, for grade 3+ radiation pneumonitis, IMRT (vs. 3D CRT) had decreased association with odds ratio (OR) 0.41, p=0.046, stage IIIB (vs. IIIA) had increased association OR 2.28, p=0.048, and lung V20 (%, continuous) had increase OR 1.07, p=0.026. On univariate analysis, lung V5 was not associated with grade 3+ radiation pneumonitis (OR 1.02, p=0.135).

Reference:

264. Which of the following describes the role of γH2AX in DNA DSB repair?

A. Signals damage to the MRN complex
B. Recruits ATM to the damage site
C. Marks sites of DNA damage
D. Promotes HR repair

Key: C

Rationale:
Phosphorylation of H2AX is a very early step in the response of mammalian cells to DNA double strand breaks and signals the presence of a radiation-included DNA double strand break. Phosphorylation of H2AX can occur via ATM; ATM promotes phosphorylation and recruits and activates other repair factors. The activation of the MRN complex is generally regarded as an initial event to recruit repair factors to sites of DNA double strand breaks; and the complex is not involved with phosphorylating H2AX. H2AX does not have a functional role in promoting HRR or NHEJ of DNA DSBs.

Reference:
265. A CT acquired with an abdominal compression device is registered with a CT acquired at the same time without abdominal compression. What anatomical structure best aligns using a rigid image registration technique?

   A. Liver  
   B. Stomach  
   C. Spleen  
   D. Spine

Key: D

Rationale: Abdominal compression causes deformation of the soft tissues, while the spine is largely unaffected.


266. What is the MOST appropriate management for a 37-year-old patient with Stage IA nodular sclerosing Hodgkin lymphoma, non-bulky, involving the right cervical neck, with baseline ESR of 15 and LDH of 200?

   A. ABVD x 2 cycles + no RT  
   B. ABVD x 2 cycles + 20 Gy RT  
   C. ABVD x 4 cycles + 20 Gy RT  
   D. ABVD x 4 cycles + 30 Gy RT

Key: B


Rationale: B is the winning arm of HD 10 GHSG trial for early favorable risk disease.
267. Which of the following materials has the highest bremsstrahlung x-ray production efficiency?

A. Titanium (Z=22)
B. Rhodium (Z=44)
C. Silver (Z=47)
D. Iridium (Z=77)

Key: D

Rationale:
Bremsstrahlung production efficiency is proportional to the target atomic number and the accelerating voltage of the electrons. For a fixed voltage, the higher atomic number target will have the higher efficiency.

Reference:

268. Which of the following agents is most similar in mechanism of action to panitumumab?

A. Sunitinib
B. Bevacizumab
C. Infliximab
D. Cetuximab

Key: D

Rationale:
Cetuximab is a chimeric IgG1 antibody to the epidermal growth factor receptor (EGFR) and is used to treat head and neck cancers and metastatic k-ras wild- type colorectal cancers. Pantimumab is a humanized IgG2 monoclonal antibody targeting the EGFR. Sunitinib is a multi-tyrosine kinase receptor inhibitor. Bevacuzmab acts on the VEGF-A ligan. Infliximab is used to treat autoimmune disorders and is an antibody against the tumor necrosis factor- alpha.

Reference:
269. What mediates tumor cell kill when the boron containing drug ($^{10}$B enriched sodium borocaptate, Na$_2$B$_{12}$H$_{11}$SH) is irradiated with low energy neutrons?

A. Low LET neutrons
B. Production of low LET protons
C. High LET alpha particles
D. Low LET carbon ions produced

Key: C

Rationale:
The production of high LET alpha particles and $^7$Li occurs when a drug containing boron (such as BSH) is irradiated with low energy neutrons during boron neutron capture therapy. The short path range of the high LET alpha particles cause local irradiation and provide some tumor selectivity for boron containing drugs providing the drugs can be selectively delivered/localized to the tumor.

Reference:

270. In an update of a meta-analysis (Rich et al.) what was the complete response (CR) and overall response (OR) rates with the use of single fraction treatment (vs multiple fraction) palliative RT fractionation for bone metastases?

A. Lower CR but similar OR
B. Similar CR but higher OR
C. Similar CR and OR
D. Lower CR and OR

Key: C

Rationale:
In intention-to-treat analysis, the overall response rate was similar in patients for single fraction treatments (61%; 1867/3059) and those for multiple fraction treatments (62%; 1890/3040). Similarly, complete response rates were nearly identical in both groups (23% vs 24%, respectively). Re-treatment was significantly more frequent in the single fraction treatment arm, with 20% receiving additional treatment to the same site versus 8% in the multiple fraction treatment arm (p < 0.01). No significant difference was seen in the risk of pathological fracture at the treatment site, rate of spinal cord compression at the index site, or in the rate of acute toxicity.

Reference:
271. How does hyperthermia enhance radiation-induced tumor growth delay?

A. Decreases tumor oxygenation  
B. Decreases formation of DNA lesions  
C. Inhibits repair of DNA damage  
D. Inhibits the blood supply to the tumor

**Key:** C

**Rationale:**
While not all mechanisms by which hyperthermia enhances the effects of radiation in cancer treatment are known, there is evidence for increased tumor perfusion and oxygenation, induction of cell death, inhibition of DNA repair, and induction of an immune response. The application of hypothermia at the time of irradiation inhibits protein function because of protein denaturation, and proteins involved in radiation-associated DNA repair pathways are affected and their function inhibited—leading to heat radiosensitization. If tumor cells are killed, the number of clonogens is reduced and therefore tumor volume doubling time increases, and as the tumors grow more slowly this decreases tumor growth rates. In biological assays, this is translated as an increased tumor growth delay to a specific volume endpoint.

**Reference:**

272. Based on an individual-patient-data meta-analysis, which of the following dosimetric constraints was the best predictor of clinically significant radiation esophagitis?

A. Mean > 20 Gy  
B. Mean > 30 Gy  
C. V60Gy > 17%  
D. D_{max} > 70 Gy

**Key:** C

**Rationale:**
On multivariable analysis of individual-patient-data of patients who underwent concurrent chemoradiation therapy for locally advanced non-small cell lung cancer, the esophageal volume receiving ≥60 Gy (V60) alone emerged as the best predictor of grade ≥ 2 and grade ≥ 3 radiation esophagitis. Recursive partitioning identified 3 risk groups: low (V60<0.07%), intermediate (V60 0.07% to 16.99%), and high (V60≥17%).

**Reference:**
In a study of pediatric brain tumor patients with a median follow-up of 3 years, how did the neurocognitive function of patients treated with focal proton radiotherapy compare to that of patients treated with surgery alone?

A. Worse processing speed and worse working memory  
B. Worse processing speed and similar working memory  
C. Similar processing speed and worse working memory  
D. Similar processing speed and similar working memory

**Key:** D

**Rationale:**
In a study of pediatric brain tumor patients at a median of 2.9 years after treatment, patients treated with focal proton therapy had similar neurocognitive function compared to patients treated with surgery alone. This was true across all domains studied, even including domains such as processing speed and working memory that are known to be especially radiation sensitive.

**Reference:**

What is the risk of progression of solitary bone plasmacytoma to multiple myeloma in 10 years?

A. 10 - 25%  
B. 30 - 50%  
C. 65 - 85%  
D. > 90%

**Key:** C

**Reference:**
275. On ACNS0121, what was the 5-year EFS for pediatric patients with classic supratentorial ependymoma status post GTR, defined as no residual cells under the operative microscope and no residual tumor on post-operative imaging, who did not receive adjuvant radiation?

A. 46%
B. 61%
C. 76%
D. 91%

Key: B

Rationale:
ACNS0121 was the first prospective trial to observe patients with classic differentiated supratentorial ependymoma after GTR. Although the 5-year EFS was 61%, the 5-year OS in this group was 100%.

Reference:

276. Energy loss by fast neutrons undergoing scattering with nuclei is especially efficient for hydrogen because:

A. the hydrogen nucleus only has a single unit of elementary positive charge.
B. the mass of a neutron is close to the mass of a hydrogen nucleus.
C. neutrons can penetrate the hydrogen nucleus more easily than higher atomic number nuclei.
D. the nuclear strong interaction is maximum for the interaction of a neutron with a hydrogen nucleus.

Key: B

Rationale:
The mass of a proton is approximately the same as the mass of a neutron. When a neutron strikes a proton, it is possible for the neutron to come almost to a complete stop, thus transferring almost all its kinetic energy to the proton. This is not possible for heavier nuclei because momentum cannot be conserved. There is an analogy with billiards. The cue ball can strike another billiard ball and come to a complete stop, transferring all its energy to the target ball. If the cue ball strikes a bowling ball it cannot lose all its kinetic energy in a single collision.

Reference:
277. Why are more monitor units typically required for IMRT than for 3D CRT?

   A. Dose per fraction is typically higher for IMRT than for 3D CRT
   B. A higher beam energy is used for IMRT than for 3D CRT
   C. IMRT employs more fields than 3D CRT
   D. Large portions of the fields are blocked in IMRT compared to 3D CRT

Key: D

Rationale:
IMRT uses many small field beam shapes to build up an ideal photon fluence for each field. These small fields cover only a portion of the target in the beam’s eye view at any given time. Therefore, we are blocking most of the target during the treatment, making the delivery less efficient in terms of monitor units. More monitor units are required to deliver the same dose to the target as compared to 3D-CRT where the fields are generally open and treating the entire target at all points during delivery.

Reference:

278. What is the principal interaction process of megavoltage X-rays in tissue?

   A. Pair production
   B. Photoelectric effect
   C. Compton effect
   D. Coherent scatter

Key: C

Rationale:
For photons in the energy range used typically in radiotherapy (150 keV to 3 MeV, the Compton process is predominant. Pair production occurs when a photon of greater than 1.02 MeV interacts with a nucleus to form an electron-positron pair. The photoelectric effect is predominant for photons that have energies less than approximately 100-150 keV, typical of X-rays used in diagnostic radiology. Photodisintegration occurs at photon energies much higher than those used in either diagnostic radiology or radiation therapy.

Reference:
279. Which parameter provides prognostic information for patients with follicular lymphoma (FLIPI index)?

A. Extranodal site  
B. ESR  
C. Age ≥ 60 years  
D. “B” symptoms

**Key:** C

**Rationale:**
All other choices are prognostic factors for early-stage classical HL, not FL. Also, ref to NCCN Guidelines-Non-Hodgkin Lymphoma Version 2019, NCCN Clinical Practice Guidelines in Oncology. The IPI risk factors include age ≥ 60, Stage III-IV, number of nodal sites ≥ 5, increased ≥ LDH, and reduced hemoglobin (<12 g/dL).

**Reference:**

280. What mechanism mediates normal tissue selectivity of amifostine (WR-2721) relative to tumor cells for protecting against radiation-induced DNA damage?

A. Pro-drug activation only in normal cells  
B. Activates damage repair only in normal cells  
C. Binds to apoptosis receptors only in normal cells  
D. Induces rapid proliferation in normal cells

**Key:** A

**Rationale:**
Amifostine (WR-2721) is an inactive prodrug that is converted to its active form (WR-1065) by alkaline phosphatase that is expressed in normal endothelium. The expression and activity of alkaline phosphatase in tumors is reduced, leading to limited conversion of WR-2721.

**Reference:**
281. In a hypothetical radiobiology experiment, what would have the largest impact to increase the RBE for carbon ions to low doses that give high levels of survival?

A. Inhibit DNA repair  
B. Fractionated dose delivery  
C. Addition of radiosensitizing drug  
D. Increase oxygen concentration

**Key:** B

**Rationale:**
A cell line with a higher α/β would have little sublethal damage repair for X-rays or neutrons, thus the RBE would be lower. The RBE is larger at a low dose rate than for a high dose rate because the effectiveness of the charged particles decreases with increasing dose rate to a lesser degree than for x-rays. For a given charged particle, the LET (and therefore the RBE) is inversely related to energy. Decreasing dose per fracture increases the RBE because the dose response for low LET radiations like x-rays have broad shoulders, indicating increased greater sublethal damage that is not observed with higher LET radiations, which have linear survival curves with no (or minimal) shoulders. Therefore, at low dose and high survival the low LET curve has a broad shoulder while high LET is no shoulder and at an isoeffect survival level then difference is greatest, especially when compared to high dose-low survival when both low LET and high LET survival curves are linear.

**Reference:**

282. What protein plays an important role in the extrinsic apoptotic pathway through activation of caspase 8?

A. RAF1  
B. RHO  
C. MEK  
D. FADD

**Key:** D

**Reference:**

**Rationale:**
FADD (FAS-associated death domain) protein plays an important role in the extrinsic apoptotic pathway through activation of caspase 8. Activated RAS stimulates cellular proliferation through activation of multiple pathways including the RAF, MEK, JNK, RAC/RHO, PLC and PI3K/AKT pathways.
283. For which patients with Wilms tumor is surgery alone appropriate?

A. Patients with Stage 1 disease with favorable histology and absence of LOH of 1p and 16q
B. Patients < 2 years of age, with favorable histology and nephrectomy weight < 550 grams
C. Patients with Stage 1 disease or those with favorable histology and absence of gain of 1q
D. Patients < 2 years of age, with favorable histology and absence of LOH of 1p and 16q

Key: B

Rationale:
AREN0532 enrolled patients with very low risk Wilms tumor defined as stage I favorable histology Wilms tumors with nephrectomy weight <550g and age at diagnosis <2 years. Very low risk patients were able to forgo systemic therapy and radiation therapy exposure and maintain excellent outcomes (4 yr EFS 89.7%, 4 yr OS 100%). 11p15 methylation status was associated relapse and may be used as a risk stratification factor for future studies.

Reference:

284. What dose and dose fractionation are considered “low-dose” total skin electron RT for the management of mycosis fungoides?

A. 4 Gy in 2 Gy/fx
B. 8 Gy in 4 Gy/fx
C. 12 Gy in 1 Gy/fx
D. 24 Gy in 2 Gy/fx

Key: C

Rationale:
12 Gy at 1 Gy/fraction is considered an effective low-dose total skin electron beam treatment.

Reference:
285. What were the toxicity/oncological outcomes in the CONVERT trial by Faivre-Finn et al. that randomized patients with limited stage SCLC to 66 Gy in 33 once daily fx or 45 Gy in 30 twice daily fx demonstrate?

A. Higher rates of grade 3-4 esophagitis with twice daily radiation  
B. Higher rates of grade 3-4 radiation pneumonitis with once daily radiation  
C. Higher local PFS with twice daily radiation  
D. Similar OS between the two arms

Key: D

Rationale: The trial was designed to show a 12% higher overall survival at 2 years in the once-daily group versus the twice-daily group. 2-year overall survival was 56% (95% CI 50-62) in the twice-daily group and 51% (45-57) in the once-daily group (absolute difference between the treatment groups 5·3% [95% CI -3·2% to 13·7%]). Local progression-free survival also did not significantly differ between the two groups. Most toxicities were similar between the groups, except there was significantly more grade 4 neutropenia with twice-daily radiotherapy (129 [49%] vs 101 [38%]; p=0·05). In patients assessed for radiotherapy toxicity, there was no difference in grade 3-4 esophagitis between the groups (47 [19%] of 254 patients in the twice-daily group vs 47 [19%] of 246 in the once-daily group; p=0·85) and grade 3-4 radiation pneumonitis (4 [3%] of 254 vs 4 [2%] of 246; p=0·70).


286. What was the rate of grade 4 or 5 radiation pneumonitis, based upon the 2016 Phase II study of hemithoracic intensity-modulated pleural RT (IMPRINT) after chemotherapy and pleurectomy-decortication as part of a multi-modality lung-sparing treatment?

A. 0%  
B. 7%  
C. 13%  
D. 22%

Key: A

Rationale: Of N=27 patients who underwent chemotherapy followed by pleurectomy decortication with planned hemithoracic IMRT to 50.4Gy in 28 fractions, 6 (22.2%) patients had grade 2 radiation pneumonitis (RP), 2 (7.4%) had grade 3 RP, and 0 had grade 4 or 5 RP. For the study, the total lung dose was limited to a normal tissue complication probability of 25% or less. When possible, the total mean lung dose was limited to 21 Gy or fewer; volume of the total lung receiving 20 Gy (V20Gy), from less than or equal to 37% to 40%; and contralateral lung (V20Gy) to 7% or less. There was no V5Gy limit, and no boost dose was delivered.

287. Why would cell survival decrease with a longer inter-fraction interval when proliferating mammalian cells are irradiated with two doses of 7 Gy?

A. Reconstitution of p53 function
B. Repair of sublethal damage
C. Reassortment into cell cycle phases
D. Reoxygenation

Key: C

Rationale:
During the time interval between the two doses, cell cycle progression would and radioresistant cells that survived the first dose would progress into a more radiosensitive cell cycle phase, and when irradiated with the second dose more cell killing would occur. Sublethal repair would also occur in the time interval but this would INCREASE cell survival; not decrease cell survival. Reconstitution of p53 does not occur and enhanced p53 would increase survival by promoting checkpoint activation and repair. Reoxygenation would INCREASE cell killing by reoxygenating radiation-resistant hypoxia cells. Cycling cells re-assortment into more sensitive portions of the cell cycle, such as G2 or M.

Reference:
Radiobiology for the Radiologist, Seventh ed. Chapter 2; page 69.

288. What BEST describes the beam quality of a photon beam?

A. Stability
B. Dose rate
C. Flatness and symmetry
D. Energy and penetrative characteristics

Key: D

Rationale:
Beam quality refers to the energy spectrum of the photons which make up a beam. A photon beam used in radiotherapy is poly-energetic consisting of photons with energy up to the accelerating potential (e.g. 6 MV, 18 MV). The average energy for a megavoltage beam is 1/3 of the accelerating potential. The stability, flatness and symmetry, and dose rate are other important characteristics of a beam but are not what defines the beam quality.

Reference:
289. In which cell cycle transition is CDK1/cyclin B involved?

A. G0-G1  
B. G2-mitosis  
C. S-G2  
D. M-G1

Key: B

Rationale:
The CDK1/cyclin B complex plays an important role in the transition of cells from G2 phase into mitosis. G0-G1 checkpoint involves cyclin D and CDK4/6; S phase to G2 transition is cyclin A and CDK2.

Reference:

290. What is the minimum radiation dose for a patient with Stage I NK/T-cell Lymphoma for optimal outcomes?

A. 24 Gy  
B. 30.6 Gy  
C. 40 Gy  
D. 50.4 Gy

Key: D

Rationale:
Dose response over 50.4 Gy has been demonstrated in many studies. Also, ref to NCCN Guidelines- Non-Hodgkin Lymphoma Version 2019, NCCN Clinical Practice Guidelines in Oncology.

Reference:
291. What drug undergoes metabolic reductive activation in hypoxic cells to generate an alkylating agent that cross-links DNA?

A. Dactinomycin  
B. Mitomycin C  
C. Plicamycin  
D. Bleomycin

**Key:**  B

**Rationale:**
Mitomycin C (MMC) is a chemotherapeutic drug that requires an enzymatic bioreduction to exert its biological effects. Upon reduction, MMC is converted into a highly reactive bis-electrophilic intermediate that alkylates cellular nucleophiles. Alkylation of DNA is the most favored mechanism of action for MMC, but other modes of action, such as redox cycling and inhibition of rRNA, may also contribute to the biological action of the drug. Plicamycin - RNA synthesis inhibitor. Dactinomycin binds to double stranded DNA through intercalation between adjacent guanine-cytosine base pairs, inhibits all forms of DNA-dependent RNA synthesis. Bleomycin induces strand breaks in DNA.

**Reference:**

292. What influences the yield of INITIAL strand breaks in DNA produced during irradiation?

A. Cellular levels of RAD51  
B. Acetylation of histones  
C. Activation of ATM  
D. Absence of oxygen

**Key:**  D

**Rationale:**
The absence of RAD51, which is a recombinase that plays a role in homologous recombinational repair, may affect the repairability of DNA double-strand breaks, but not their initial yield. Activation of ATM is a biological process that occurs in response of the radiation-induced DNA breaks. Acetylation of histones does not impact the number of DNA breaks produced in DNA. The absence of oxygen means the cells are hypoxic, there is less molecular oxygen present and therefore few DNA radicals are formed that can damage DNA.

**Reference:**
293. According to AAPM TG-142 recommendations, which QA test should be conducted on a daily basis?

A. Radiation and light field congruence  
B. MLC positioning accuracy  
C. Door and collision interlocks  
D. CBCT image quality relative to baseline

**Key:** C

**Rationale:**
Beam on indicators and door interlocks are critical for patient and staff safety and should be verified daily. The other tests should be performed on a more infrequent basis.

**Reference:**

294. Which patient with a cancer predisposition syndrome should undergo screening for Wilms tumor?

A. Gorlin syndrome with PTCH1 mutation  
B. Neurofibromatosis type 1 with a NF1 mutation  
C. Beckwith-Wiedemann syndrome with 11p15.5 alteration  
D. Malignant rhabdoid tumor syndrome with SMARCB1 mutation

**Key:** C

**Rationale:**
A review of patients treated on the National Wilms Tumor Study Group protocols showed that there was a trend toward smaller tumors over time in BWS patients suggesting that existing screening protocols within this population led to earlier detection. Cost-benefit analysis of a screening approach for Wilms tumor in BWS patients confirmed the practice to be cost-effective and potentially better outcomes. Gorlin, Neurofibromatosis type 1 and malignant rhabdoid tumor syndrome patients are not at risk for Wilms tumor and would not benefit from surveillance for this tumor type.

**Reference:**
295. For a CT simulation of a hypo-dense liver lesion, a 4D CT study is performed to assess the lesion motion and generate an ITV. Which CT dataset best delineates the ITV?

A. Average intensity projection (AIP)
B. Maximum intensity projection (MIP)
C. Minimum intensity projection (MinIP)
D. 50% phase dataset

Key: C

Rationale:
Since the lesion is hypo-dense, the HU of the lesion will be less than that of the surrounding normal liver. To obtain the lesion motion envelope—i.e. ITV, the MinIP would better depict the motion envelope.

Reference:

296. Globally, what percent of cancer is estimated to be caused by infections?

A. 1 - 2
B. 5 - 10
C. 15 -20
D. 40 -50

Key: C

Rationale:
Worldwide, infections are linked to about 15-20% of cancers.

Reference:
297. Which mutation is MOST commonly found in diffuse intrinsic pontine glioma?

A. BRAF V600E  
B. H3 K27M  
C. IDH R132H  
D. SMARCB1

Key: B

Rationale:
At least two-thirds of DIPGs have H3 K27M mutations. Only 6% of midline gliomas have BRAF V600E or IDH R132H mutations. SMARCB1 mutations are associated with ATRT.

Reference:
Mackay et al., 2017, Cancer Cell 32, 520-537.

298. What is the Dose Rate and Dose Rate Effectiveness factor recommended by ICRP to reduce cancer risk estimates from low dose rate exposures?

A. 1.5  
B. 2.0  
C. 2.5  
D. 3.0

Key: B

Rationale:
The Dose and Dose Rate Effectiveness Factor is defined as:

\[ DDREF = 1 + \frac{D}{\alpha/\beta} \]

Where \(D\) is dose and \(\alpha\) and \(\beta\) are the linear and quadratic proportionality coefficients respectively from the acute cancer dose response fit to a linear quadratic model. As the value for DDREF from animal studies have proven to be highly variable, the ICRP has chosen the conservative value of 2 for this parameter.

Reference:
299. Which of the following characteristics is ideal for a desirable ion chamber?

A. Chamber calibration factor is energy dependent
B. Chamber response is directionally dependent
C. Chamber stem leakage is small
D. Chamber ion recombination is high

Key: C

Rationale:
An ideal ion chamber should not be energy dependent, should exhibit minimal directional dependence, and should have minimal ion recombination.

Reference:

300. What is the shape of a survival curve of hypoxic mammalian cells treated with high-LET alpha particles?

A. Non-linear threshold, then linear
B. Linear with little or no shoulder region
C. Linear quadratic
D. Linear quadratic with final slope

Key: B

Rationale:
Alpha particles have a very low OER, which corresponds with a high LET and thus would induce more cell kill per culture condition than lower LET radiations (with higher OER’s). Sparing at an OER of 1 with alpha particles is unlikely in hypoxic environments vs aerated conditions, and as such the cell survival curve will have little or no shoulder. Likewise, little sparing will be observed in less radiosensitive portions of the cell cycle.

Reference:
Radiobiology for the Radiologist, Seventh ed. 86-89, 64.